

Civil Drafting Technology

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EIGHTH EDITION



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Preface

Civil Drafting Technology is a basic thorough advanced civil drafting textbook appropriate for use by students enrolled in any secondary or postsecondary drafting or related course, and for anyone who is interested in learning about civil drafting theory and applications. Students will explore the design and drafting principles and practices used in the civil drafting field. Students are acquainted with civil drafting disciplines, mapping, computer-aided design and drafting (CADD), surveying, locations, distances, angles, directions, contour lines, site plans, horizontal alignments, profiles, earthwork, detail drawings, and geographic information system (GIS).

American Design Drafting Association (ADDA) Approved Publication

The content of this text is considered a fundamental component to the design drafting profession by the American Design Drafting association. This publication covers topics and related material, as stated in the ADDA curriculum certification standards and the ADDA certified drafter examination review guide. Although this publication is not conclusive with respect to ADDA standards, it should be considered a key reference tool in pursuit of a professional design-drafting career.

Approach and Purpose

Civil Drafting Technology offers a workbook approach that provides comprehensive civil drafting instruction. This textbook has been tested in the classroom and was created with input from civil engineering industry professionals and educators. The primary objectives of ***Civil Drafting Technology*** are to provide students with a foundation of the work done by civil engineering companies and a broad education in the civil drafting field, which includes associated drawings, skills, and terminology. Most civil engineering drawings and maps are generated by CADD software, and a variety of data often collected using electronic surveying techniques. Regardless of the CADD software used, a drafter must have knowledge of how maps and drawings are created.

Civil Drafting Technology is arranged in 14 chapters, each dealing with a specific subject area. Each chapter provides realistic

examples, illustrations, review questions, and problems. The examples illustrate recommended drafting and design presentation based on civil drafting standards, with actual industry drawings used for reinforcement. The correlated text explains drafting techniques and provides professional applications for skill development. Layout methods offer a logical approach to setting up and completing drafting problems. The content, review questions, and problems can fit a variety of course formats and lengths. When used in the prescribed manner, ***Civil Drafting Technology*** provides a broad understanding of civil drafting and a working knowledge of the basic components of mapping.

The knowledge and skills students gain from this textbook opens a variety of job opportunities, and these opportunities can offer an inspiring career. Careers found in civil drafting can be filled with variety and excitement, and can include disciplines such as CADD, surveying, construction, courthouse research, artistic interpretation, mapping, and cartography. Civil drafting and mapping requires accuracy, neatness, and an eye for creative and uncluttered layout. ***Civil Drafting Technology*** provides a practical approach to drafting as related to standards typically found in the civil engineering industry. This textbook also serves as a valuable desk reference for civil drafting professionals.

Features

Civil Drafting Technology delivers easy-to-read, comprehensive, and highly illustrated coverage of civil drafting practices that conform to industry standards. Each chapter provides complete descriptions, real-world practices, realistic examples, illustrations, and related assignments associated with chapter content. The examples illustrate typical civil drafting practices used throughout the civil engineering field. Chapters are organized in a format that is consistent with the process used to take civil engineering projects from preliminary concept through all phases of design and documentation.

This textbook includes many features to guide readers through the world of civil drafting. Chapter learning objectives, for example, provide motivating learning goals that act as an effective road map of each chapter and help students track their learning. Another example is the Note box feature used where appropriate to provide reference to other chapters, additional explanation, helpful tips, professional information, or alternate practice.

This textbook provides a broad and highly useful range of content that is not found in another single textbook. From generic design and drafting theory, to maps and map making, to surveying, to specific civil design and drafting applications; this textbook provides enough information about a wide variety of topics to benefit many different courses and programs, and by anyone interested in a quality overview of civil drafting technology and related disciplines. The following information describes several other special features found in this textbook.

Industry Approach to Problem Solving

This textbook explains how to prepare drawings by providing basic guides for layout and arrangement in a systematic knowledge-building format. One concept is learned before the next is introduced. The concepts and skills learned in one chapter are used in the next chapters, so that by the end of the text, students have the ability to solve problems using a multitude of skills learned previously through discussions, examples, and activities. Each chapter provides realistic examples, illustrations, review questions, and problems. The examples illustrate recommended drafting and design presentation based on civil drafting standards, with actual industry drawings used for reinforcement. The correlated text explains drafting techniques and provides professional applications for skill development. Step-by-step layout methods provide a logical approach to setting up and completing drafting problems.

Numerous High-Quality Illustrations

Real-world drawings, images, and other illustrative examples are used generously throughout this textbook to support text content. The figures in this textbook are clear, easy to understand, provide appropriate detail, and are consistent throughout. Many illustrations show actual civil drafting examples used to illustrate chapter content.

Computer-Aided Design and Drafting (CADD)

CADD applications throughout this textbook illustrate how the use of CADD is streamlining the civil engineering design and drafting process. The authors describe current CADD procedures and techniques including: CADD software used in drafting and design, U.S. National CAD Standards, CADD templates, CADD layers, CADD material requirements, specific CADD applications, file management, plotting guidelines, CADD symbols for specific civil engineering drafting applications, increased productivity with CADD, reuse of drawing content with CADD, the CADD environment in industry, and ergonomics. The focus of this textbook is not instruction in one specific brand of software or one specific software product. Autodesk's AutoCAD is often mentioned due to its popularity. Although specific software products are mentioned, it is not imperative that the student use those products to learn the materials presented in this textbook.

Chapter Review

A content-related review, or test, is provided at the end of each chapter for examination or review. Reviews include a variety of questions, such as short-answer, multiple-choice, true-and-false, sketching, and print reading exercises to help students understand chapter content. Chapter review questions provide excellent review of chapter content, and allow readers to further examine and reconsider chapter subject matter. Review questions also act as an effective assessment tool. Students can provide answers to chapter review questions

manually by removing the perforated pages for convenient use, or can access the **Student Resources** at <http://www.pearsonhighered.com/careersresources/> to download the questions.

Chapter Problems

Each chapter ends with real-world industry review and drafting and design problems for students to practice what they have learned. Problems vary from basic through complex, and are presented in order of difficulty. Problems include engineering sketches, engineering layouts, written instructions, and actual industry projects. The problems are presented in a manner that is consistent with the civil engineering environment. The goals and objectives of each assignment are consistent with recommended evaluation criteria based on the progression of learning activities. Some chapter problems include a PowerPoint feature that allows students to create and present PowerPoint slides directly related to the textbook content and examples.

Civil Drafting Technology Digital Resources (<http://www.pearsonhighered.com/careersresources/>)

The Civil Drafting Technology Digital Resources contain Microsoft Word .doc files for all Chapter Reviews, .pdf files for Chapter Review print reading questions, AutoCAD .dwg files for certain Problems, AutoCAD .dwt template files, and related weblinks. Go to www.pearsonhighered.com/careersresources/ and navigate to this textbook to access the Digital Resources.

Suggested Course of Study

By studying ***Civil Drafting Technology*** and enrolling in a course in which students can apply the concepts presented, students are providing themselves with an excellent civil drafting foundation. If students are interested in expanding their knowledge and skills in civil drafting and design, they should enroll in advanced civil courses, surveying courses, or courses that provide training in specialized civil design and drafting software and geographic information systems (GIS). A wide variety of civil engineering design, modeling, drafting, and GIS software is used today.

To access supplementary materials online, instructors need to request an instructor access code. Instructors can go to www.pearsonhighered.com/irc, where they can register for an instructor access code. Within 48 hours after registering, the instructor will receive a confirmation email that provides an instructor access code. After the instructor receives their code, they can go to the site and log on for full instructions on downloading the desired materials.

Special Note on the Eighth Edition

Civil Drafting Technology is a very unique textbook. There is no other product available today that effectively addresses all of the topics found in this textbook. A great deal of effort has gone into making

the ***Eighth Edition*** of this textbook better than ever before. This edition offers accurate, up-to-date content that is clearer, better organized, and easier to understand than in previous editions. This edition has updated content to reflect current practices, while retaining some traditional information as background. New material has been added to support CADD in civil engineering. All chapters have been updated with information about current practices.

Nearly all of the figures and other illustrations have been redrawn or recaptured so that all figures are now easier to read and understand, up-to-date, better represent and convey text content, and are consistent. Additional figures have been incorporated throughout to better illustrate content. New and updated chapter review sections offer more review questions and print-reading exercises to help reinforce chapter content. New and updated chapter problems offer more review, study, and drafting and design exercises to help reinforce chapter content and provide students the opportunity to practice what they have learned.

Students, instructors, and reviewers all provide valuable input to the content and revisions of a textbook such as this. The authors welcome your comments and suggestions. Please direct comments to one of the editors at Pearson listed in the front of the textbook.

Instructor Resources

The ***Instructor Resources*** for ***Civil Drafting Technology***, found at www.pearsonhighered.com/irc, include the following components to help minimize instructor preparation time and engage students, and to help educators develop civil drafting technology courses.

Syllabus

Lesson plans created by chapter are available with the Instructor's Manual. Instructors have the option of using these lesson plans with their own course information.

PowerPoint Presentation

Slides for each chapter of the text provide the basis for a lecture outline that helps instructors to present concepts and material. Key points and concepts can be graphically highlighted for student retention.

Solutions Manual

A Solutions Manual with answers to end-of-chapter review questions and solutions to end-of-chapter problems.

Final Exam

A sample final exam provided with the Instructor's Manual that can be used to test students at the end of the course of study.

Special thanks are extended to the professionals who provided comprehensive reviews of the text and assisted with new content. The quality of this textbook is improved by the support and contributions from designers, engineers, surveyors, and vendors. Acknowledgment is given at each illustration. The following individuals and companies or agencies, in alphabetical order, gave exceptional support with technical information and art for this edition.

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Contents

Chapter 1

INTRODUCTION TO CIVIL DRAFTING TECHNOLOGY 1

- Civil Engineering 2
- Employment Opportunities 3
- Education and Qualifications 4
- Professional Organizations 5
- Map Fundamentals 7
- Types of Maps 10
- The Design and Drafting Process 23
- Drafting Standards 32
- Workplace Ethics 36

Chapter 2

COMPUTER-AIDED DESIGN AND DRAFTING (CADD) 45

- Civil CADD Software Products 46
- CADD Formats 48
- Building Information Modeling (BIM) 49
- The U.S. National CAD Standard (NCS) 54
- Basic CADD Techniques 54
- Sheet Size and Format 65
- Plotting 70
- File Organization 73
- Productivity with CADD 75
- Ergonomics 76

Chapter 3

MAP SCALES 85

- Map Scale 86
- Numerical Scale 86
- Graphic Scale 87
- Verbal Scale 92
- Scale Tools 92
- CADD Scales 96

Chapter 4

MAP SYMBOLS 107

Types of Map Symbols 108

Legends 113

Creating and Using Symbols 113

Chapter 5

INTRODUCTION TO SURVEYING 129

Geodetic Surveys 130

Plane Surveys 132

Types of Surveys 133

Conventional Ground Surveying 139

Data Collection 139

Field Notes 142

Global Navigation Satellite System (GNSS) 146

3-D Laser Scanning 150

Chapter 6

LOCATIONS AND DISTANCES 163

Cartesian Coordinate System 164

Geographic Coordinate System 166

Map Projections and Coordinate Systems 173

Locations on Quadrangle Maps 179

Horizontal Distances 179

Vertical Distances 183

Chapter 7

ANGLES AND DIRECTIONS 203

Angles 204

Directions 206

Traversing 211

Plotting Traverses 215

Chapter 8

CONTOUR LINES 233

- Contour Lines 234
- Types of Contour Lines 241
- Plotting Contour Lines 244
- Contour Lines with Civil CADD 253

Chapter 9

SITE PLANS 267

- Plan Views 268
- Site Plan Requirements 268
- Describing and Locating Property 276
- Utilities on a Site Plan 285
- Sewage Disposal Methods 285
- Site Design Considerations 288
- Site Plan Layout 293

Chapter 10

HORIZONTAL ALIGNMENTS 315

- Plan Layout 316
- Horizontal Curves 318
- Horizontal Alignments with Civil CADD 323

Chapter 11

PROFILES 339

- Profile Layout 340
- Plan and Profile 343
- Vertical Curves 352
- Profiles with Civil CADD 354

Chapter 12

EARTHWORK 373

- Cut and Fill 374
- Route Cut and Fill 374
- Site Cut and Fill 380

Cross Sections	383
Earthwork Calculations	386
Earthwork with Civil CADD	390

Chapter 13

DETAIL DRAWINGS 407

Detail Drawing Format	408
Standard Details	410

Chapter 14

INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEM (GIS) 453

GIS Software Products	454
Basic GIS Concepts	456
GIS Applications	465
Related GIS Disciplines	472

GLOSSARY 479

ABBREVIATIONS 497

INDEX 505



CHAPTER

1

Introduction to Civil Drafting Technology

Learning Objectives

After completing this chapter, you will be able to:

- Define civil engineering and civil drafting.
- Identify civil drafting employment opportunities.
- Describe the education and qualifications required to be a civil drafter.
- Identify professional civil engineering and civil drafting organizations.
- Define terms and elements related to maps and civil drafting.
- Identify a variety of map types.
- Describe the design and drafting process.
- Explain the purpose and provide examples of drafting standards.
- Discuss workplace ethics.

Key Terms

Civil engineering
Surveying
Civil drafting
Two-dimensional (2-D)
Three-dimensional (3-D)
Geomatics
Consulting engineering
Computer-aided design and drafting (CADD)
Geographic information systems (GIS)
Professional engineer (PE)
Manual drawing
Map
Charts
Elevation
Cartography
Cartographer
Border
Title block
Legend
Key
Scale
Physical map
Political map
Thematic map
Photogrammetric map
Photogrammetry
Aerial photographs
Topographic map
Contour line

(continued)

Key Terms (*continued*)

Quadrangle map	Planning map	Cutting-plane line
Geologic map	Zoning map	Typical cross section
Military map	Nautical chart	Detail drawing
Terrain	Aeronautical chart	Detail
Milliradian	Digital elevation model (DEM)	As-built survey
Mil	Digital surface model (DSM)	As-built drawing
Cadastral map	Remote sensing	As-built
Hydrographic map	Digital terrain model (DTM)	Standards
Engineering map	Surveyors	Code
Site plan	Plan view	Client
Plot plan	Plan	Specification
Plot	Vicinity map	Standards checking
Plat	Cross section view	Ethics
Subdivision	Cross section	Code of ethics
Infrastructure	Profile	Intellectual property

This textbook focuses on fundamental design and drafting theory and applications associated with common civil engineering projects. This chapter is an introduction to civil drafting technology and describes civil drafting employment opportunities, education, qualifications, and professional organizations. You will also learn about maps, the design and drafting process, drafting standards, and workplace ethics.

Civil Engineering

Civil engineering is the branch of engineering related to the planning, design, construction, and maintenance of structures. Civil engineers probably designed the construction site upon which your house or apartment, and school or office is built. The road on which you drive and the water supply system from which you drink also require civil engineering. Civil engineering is the second oldest form of engineering known, after military engineering. It is a broad discipline, and civil engineers are often involved in all phases of a construction project. Architecture, building construction and management, environmental health, material science, surveying, and transportation are a few of the many civil engineering subdisciplines. **Surveying** is the science of measuring distances, angles, and directions of characteristics of the Earth's surface.

Civil drafting is drafting performed for civil engineering. Civil drafters work with civil engineers and other industry professionals to prepare models and drawings for civil engineering projects. Examples of civil engineering projects are bridges, building sites, canals, dams, harbors, roadways, railroads, pipelines, public utility systems, and waterworks. Civil drafters create maps, plans, cross sections, profiles, and detail drawings. Projects are designed in two-dimensional (2-D) and/or three-dimensional (3-D) formats. **2-D** refers to a view displaying only width and height, width and length, or height and length. **3-D** refers to a view displaying width, height, and depth. Civil

drafters may also calculate excavation and fill volumes, and prepare graphs and diagrams used in earthmoving operations. Civil drafters can accompany survey crews in the field to collect data required to prepare or revise construction drawings.

Note: Surveying, mapping, civil engineering, and civil drafting are a few of the disciplines associated with the broad field of geomatics. **Geomatics** is the whole method of collecting, storing, managing, and presenting geographic or spatial data.

Employment Opportunities

Civil drafters are employed by consulting engineering companies; local, state, and federal government agencies; manufacturers of products and providers of services associated with civil engineering projects; and the military. **Consulting engineering** is an independent service that provides licensed and certified engineering for construction and related projects. Civil drafting job opportunities are available around the world; from rural communities to large cities.

Civil engineering is an extensive field. Therefore, civil drafters often create many different types of drawings for a variety of projects. Some civil engineering companies or agencies, especially consulting engineers, offer expertise in several areas. Other civil engineering firms specialize in certain aspects of civil engineering. The following is a list of some of the specialties in which civil engineering companies and agencies are involved:

- Agribusiness
- Construction observation
- Environmental studies
- Flood control
- Foundation work and soil analysis
- Hydrologic studies
- Irrigation and drainage
- Land and construction surveys
- Land planning and subdivision
- Map-making
- Municipal improvements
- Power plants
- Refuse disposal
- Sewage and water treatment
- Transportation

Drafting employment opportunities fluctuate with national and local economies. Employment for civil drafters is often linked with demands for construction and related industries. A national increase or decrease in construction affects the number of available drafting jobs. The economic effect on drafting job opportunities also occurs locally and within specific subdisciplines. For example, construction can be stronger in one part of the country than another, or one city or state may have more funding to apply toward municipal improvements

than another. The demand for civil drafters is accordingly higher in areas where the economy is stronger, and lower in areas where the economy is weaker. A growing number of drafters are finding employment on a temporary or contract basis as more companies and agencies turn to employment services to meet their changing needs.

Salaries for civil drafters are usually competitive with those in other professions with equal educational requirements. Working conditions vary but are usually excellent. Employment benefits differ according to each employer. However, most employers offer vacation and health insurance coverage, and some include dental, life, and disability insurance. Check your local and state employment offices and online employment resources for information about specific employment opportunities, salary ranges, and benefits.

Education and Qualifications

High schools, technical institutes, community colleges, and some four-year colleges and universities throughout North America offer drafting courses or programs. A school often focuses curriculum on the needs of industry in the immediate area. Many schools with a drafting program provide a general education with courses in a variety of drafting disciplines so that graduates have versatile employment opportunities. Some schools offer a specific civil drafting education, especially if necessary to fill the employment needs of local civil engineering companies and agencies. Identify the school and program that will best serve your specific goals. Research the curriculum and placement potential for graduates. Talk to representatives of local industries to help evaluate a school's drafting curriculum.

Students who desire to work as civil drafters should complete a one-year certificate or a two-year associate of science degree with studies in computer-aided design and drafting (CADD), civil drafting theory, and geographic information systems (GISs). **CADD** is the process of using a computer with CADD software to design and produce drawings and models according to specific industry and company standards. A **GIS** is a computerized database system used to manage, analyze, and display spatial data. Employers in the drafting industry typically prefer applicants who have at least two years of postsecondary training in a drafting program that provides strong technical skills and considerable CADD training. If you are interested in civil drafting as a career, your schooling should include math at least through basic trigonometry; application of CADD software programs; sketching techniques and skills; and the civil drafting theory, standards, and practices explained throughout this textbook.

After completing a two-year associate degree program, graduates can obtain jobs as drafters or continue education in a related field at a four-year college. A student wanting to become a civil engineer must complete four or five years of college and graduate with a bachelor of engineering or bachelor of science degree. Students can specialize in one of the wide variety of engineering subdisciplines in the final years of study. A **professional engineer (PE)** is an engineer who has a four-year degree in engineering from an accredited engineering program,

has passed the Fundamentals of Engineering (FE) exam, has completed four years of progressive engineering experience under a PE, and has passed the Principles and Practice of Engineering (PE) exam.

Note: **Manual drawing** is drafting done using traditional tools to create drawings by hand with pencil or ink on paper or other media. The need for precise hand line work, inking skills, and lettering has almost disappeared from the workplace, though occasionally the need to modify old, archived drawings does arise. However, technical sketching and CADD are the focus rather than the use of manual drafting equipment.

Professional Organizations

There are many professional organizations that offer a great deal of information and resources for engineers and drafters. Joining a professional design and drafting or related organization is a good way to further your career and expand your knowledge. Associations promote many different events and activities that can help you reach your professional goals by connecting with peers, volunteering, and sharing ideas. Most associations provide access to books, journals, magazines, articles, and other materials that are useful for learning about new concepts and practices. Some associations offer career resources such as job listings, and techniques for searching for and obtaining a job. The following information briefly explains a few of the professional associations related to civil drafting technology.

American Design Drafting Association/American Digital Design Association (ADDA)

The American Design Drafting Association/American Digital Design Association (ADDA) is a professional organization dedicated to the advancement of design and drafting and the graphics professions. The ADDA offers leadership opportunities, local professional councils, and student chapters. The ADDA also approves products based on quality, durability, usability, and value; and publications based on content relative to the design and drafting industry.

The ADDA holds the Annual Technical and Educational Conference and sponsors the Annual Design Drafting Week, Annual Poster Contest, and Annual Design Drafting Contest. Examples of other ADDA benefits are publication and product discounts, networking, members only forum, and access to publications and documents such as the *Drafting Examination Review Guides*. The following information highlights a few prominent ADDA programs for you to consider. For more information about the ADDA, go to www.adda.org.

Professional Certification Programs The ADDA professional certification exams are international certification programs that allow apprentice drafters, drafters, designers, design drafters, design technicians, engineering and architectural technicians, digital imaging

technicians, and other graphic professionals to indicate their knowledge in professional concepts and internationally recognized standards and practices. The ADDA developed these exams to elevate an individual's comprehension of the professional standards related to the design drafting and graphics professions.

Certification allows drafters to demonstrate professional capabilities and helps employers to identify quality employees. The tests do not cover specific CADD software or graphic production. The ADDA Drafter Certification Examination is open to all individuals, regardless of experience and formal education. An ADDA membership is not required to take the test or to become certified. Becoming a Certified Drafter reflects your proven knowledge of drafting. Certification enhances your credibility as a professional, improves your opportunities for promotion and pay increases, and gives you a competitive edge in a highly technical job market.

When employers hire an ADDA Certified Drafter, they know that the new employee meets certification criteria and has demonstrated initiative and pride in the profession by becoming certified. Therefore, certification can serve as one criterion for differentiating among candidates in the selection process. Certification also serves educators as a supplementary measurement of a student's performance on a recognized national level.

Employment Center The ADDA Employment Center is available to help connect ADDA members with employment opportunities. Post your résumé online if you are seeking work. Access the newest jobs available by employers to professionals seeking employment.

Instructor and Curriculum Certification Programs The ADDA Instructor Certification Program is designed to provide professional recognition to instructors, teachers, and educational professionals. Instructors must be engaged in a design drafting and graphics training program within an approved educational setting on an annual schedule with an end result of a trade or craft certificate or diploma. The ADDA Certified Curriculum Program approves curriculum that meets or exceeds industry standards.

American Council of Engineering Companies (ACEC)

The American Council of Engineering Companies (ACEC) is a national organization devoted to the business and support of engineering companies. The ACEC mission is to contribute to America's prosperity and welfare by advancing the business interests of member firms. Members range from PEs and professional land surveyors (PLSs) to consulting engineering companies and large corporations.

The ACEC advocates for, and takes political action to support, the business interests of engineering companies. The ACEC offers educational webinars, seminars, workshops, and meetings. ACEC publications include the *Engineering Inc.* magazine, *Last Word* newsletter, and *ACEC Engineering Business Index* survey. The ACEC holds two conferences per year and presents a variety of awards and scholarships. For more information about the ACEC, go to www.acec.org.

American Society for Engineering Education (ASEE)

The American Society for Engineering Education (ASEE) is a non-profit association dedicated to promoting and improving engineering and technology education. The ASEE mission focuses on developing policies and programs that enhance professional opportunities for engineering faculty members and promote activities that support increased student enrollments in engineering and engineering technology colleges and universities. Members include engineering firms, government agencies, and educational institutions.

ASEE publications include the *Prism* and *eGFI* magazines, *Journal of Engineering Education* and *Advances in Engineering Education* journals, and *Profiles of Engineering and Technology Colleges* directory. The ASEE offers educational workshops, meetings, and conferences, including the ASEE Annual Conference and Exposition. The ASEE offers fellowship programs and presents a variety of awards. For more information about the ASEE, go to www.asee.org.

American Society of Civil Engineers (ASCE)

The American Society of Civil Engineers (ASCE) is a professional organization that provides value to members, member careers, partners, and the public by developing leadership, advancing technology, advocating lifelong learning, and promoting the civil engineering profession. The ASCE publishes numerous civil engineering products including books, manuals, journals, and standards. Examples of ASCE journals are *Journal of Bridge Engineering*, *Journal of Environmental Engineering*, *Journal of Transportation Engineering*, and *Journal of Water Resources Planning and Management*. *Civil Engineering* is the monthly ASCE magazine.

The ASCE offers educational webinars, seminars, workshops, and meetings. Education and continuing education courses and programs are available to help PEs meet competency requirements. The ASCE holds several conferences per year, including an annual conference. The ASCE also offers professional certification and presents a variety of awards. For more information about the ASCE, go to www.asce.org.

Map Fundamentals

A **map** is a graphic representation of part or all of the Earth's surface, drawn to scale on a plane surface. Some maps, such as aeronautical and nautical maps, are more commonly referred to as **charts**. Maps use lines, symbols, colors, and labels to display natural features such as mountains and rivers, and areas with constructed features such as buildings and roads. Maps have many different purposes, depending on their intended use. A map can accurately provide distances, locations, elevations, best routes, land features, and much more. **Elevation** is the height of a geographic location above or below a theoretically exact reference point, axis, or plane.

Cartography

Cartography is the art of making maps and charts. A **cartographer** is a highly skilled professional who designs and draws maps. Cartographers use a variety of graphic media, computer software, and artistic illustration to create maps. Civil drafting and cartography are similar in that both professions deal with making maps. However, civil drafting is generally concerned with drawings for civil engineering projects. Cartographers often use more graphic skills in the preparation of documents and maps. A cartographer typically has completed four years of education with emphasis on cartography, civil engineering, digital imaging, geodesy, geography, navigation, and optics.

Map Elements

A map typically includes several basic elements such as a border, title, legend, information about scale and direction, and additional written labels and notes (see Figure 1–1). A **border** consists of lines that create the format margins of the sheet. Maps may or may not display a border, while civil engineering drawings usually include a border. The map title names the map. A title block often contains the title of a civil engineering drawing. A **title block** is a sheet block that

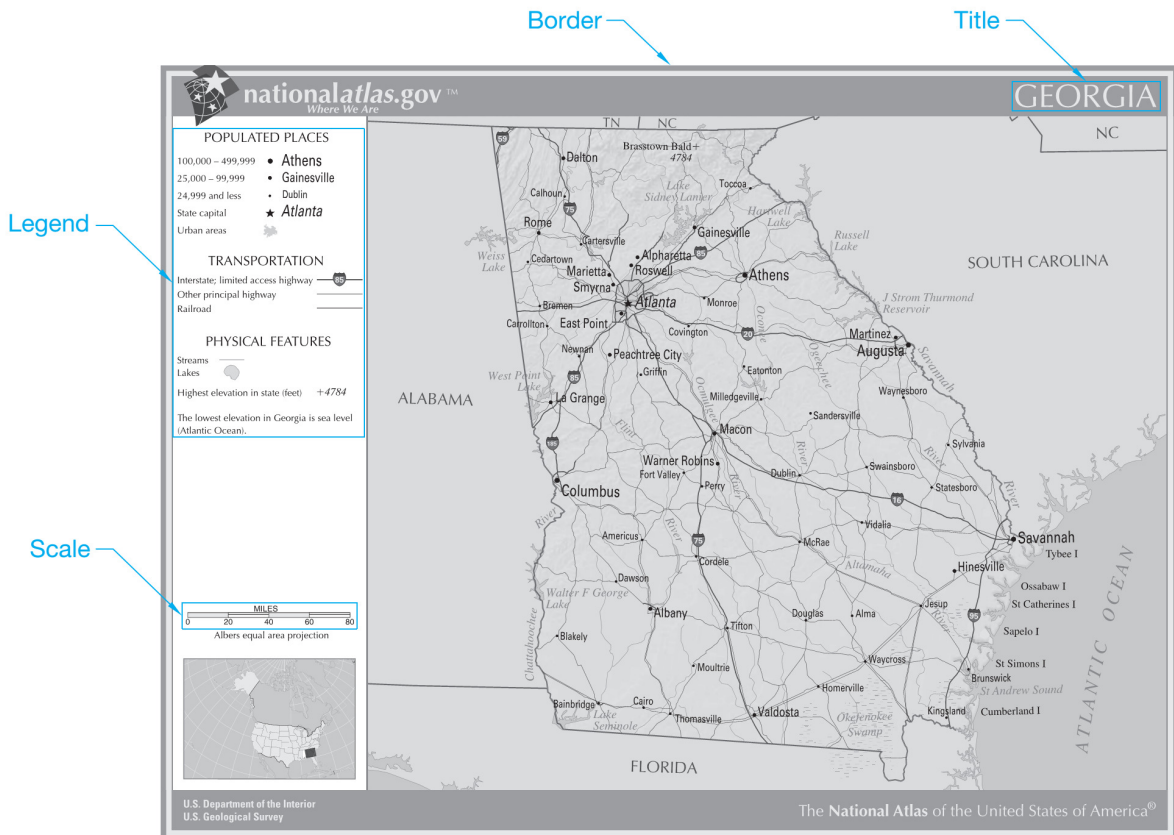
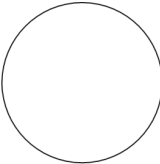


Figure 1-1. A general reference map of the State of Georgia. This map includes common map elements such as a border, title, legend, and scale.
(Courtesy of the U.S. Geological Survey)

provides a variety of information about a drawing, such as the title, sheet size, and predominant scale. Figure 1–2 shows an example of a title block. The title and information in a title block tell you immediately if you have the correct map or drawing.

Figure 1–2. A title block found on drawing for a residential construction project.

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CONWELL RESIDENCE TAX LOT 1400 KENT, WA 98030 OWNER RYAN & LISA CONWELL 14865 SE LONE ASH LN KENT, WA 98030 PHONE: 212.641.2400 FAX: 212.641.2400 EMAIL: contact@pearson.com
MANAGEMENT PROJECT NUMBER: RLC-01601 FILE NAME: G-01.dwg DRAWN BY: DPM CHECKED BY: MMM COPYRIGHT: DAVID P. MADSEN
TITLE COVER, SITE PLAN
SHEET G-01 SHEET 1 OF 15

A map **legend**, or **key**, explains the symbols, colors, and labels that make up the map or drawing data. A legend is necessary in order to understand the information presented on a map. The legend shown in Figure 1–1, for example, keys population, transportation, and physical land and water feature symbols to the map. A **scale** is an instrument with a system of ordered marks at fixed intervals used for measurement. For example, use the scale shown in Figure 1–1 to approximate the number of miles between two cities. A scale establishes a proportion used to determine the dimensional relationship of an actual object to the representation of the same object on a drawing. Scale also refers to the ratio of measuring units expressing a proportional relationship between a drawing and the full-size items the drawing represents. For example, the map of the large area shown in Figure 1–1 must be scaled down to fit on a sheet. Chapter 3 explains map scales in detail. A map may include a north arrow in order to specify orientation, especially if the map is not north-oriented. North is assumed to be facing the top of the sheet in the map shown in Figure 1–1. Therefore, the north arrow is omitted. Chapter 7 explains angles and directions in detail.

Types of Maps

There are hundreds of different types of maps. Some maps show the geography of the world, while other maps display construction sites for new homes or commercial projects. Civil engineering companies primarily prepare maps associated with the planning, design, construction, and maintenance of structures; such as construction site and roadway plans. The following information describes several of the most common types of maps. This textbook focuses on maps related to the Earth.

Physical Maps

A **physical map** displays the physical features of an area such as differences in elevation and bodies of water. Physical maps commonly display color and relief-shading that provide a descriptive representation of a portion of the Earth's surface (see Figure 1–3). Physical maps are usually prepared at a small scale and show large areas.

Political Maps

A **political map** shows the boundaries of governments such as countries, states, and counties. Political maps may identify major cities and often shows large bodies of water (see Figure 1–4). Political maps are usually prepared at a small scale and show large areas.

Thematic Maps

A **thematic map** provides information about specific topics or themes such as the amount of vegetation on the surface of the Earth, observing the effects of wildfires, or plotting human population patterns.



Figure 1-3. A physical map of the contiguous United States.
(Courtesy of the U.S. Geological Survey)

Figure 1-5 shows an example of a thematic map generated using images taken by a satellite. This particular map shows the distribution of permafrost across the mainland State of Alaska. The map provides information that can be used to model the decrease in permafrost, which has implications for many issues such as land-use planning and environmental calculations.

Photogrammetric Maps

A **photogrammetric map** is a map created from photographs, typically aerial photographs, using photogrammetry. **Photogrammetry** is the method of measuring the distance between points on photographs. **Aerial photographs** are photos taken at various altitudes and controlled by base stations at known distances on the ground to check for accuracy. Many overlapping photos are typically required to create an accurate map. Aerial photographs can be used to create orthophotos through a process known as rectification, which combines multiple overlapping images and projects the images onto a plane. Figure 1-6 shows an example of an aerial photograph. Aerial photos are accurately scaled and converted to maps using special stereoscopic instruments and computer software.

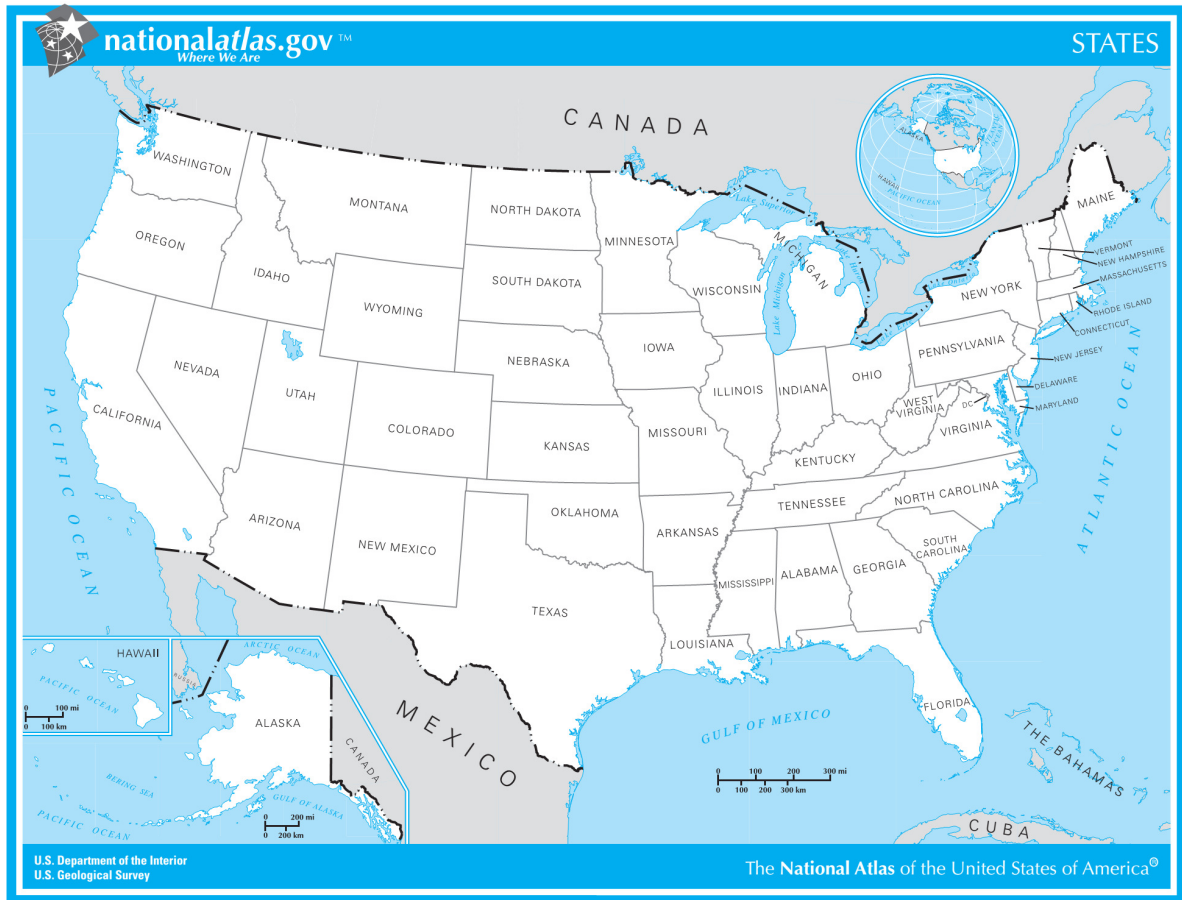


Figure 1–4. A basic political map of the United States.
(Courtesy of the U.S. Geological Survey)

Topographic Maps

A **topographic map** accurately shows the shape of the Earth using contour lines (see Figure 1–7). A **contour line** is a line that connects points of equal elevation. The spacing of contour lines is determined by the grade, or slope, of the land. On very steep terrain, contour lines are close together because changes in elevation occur quickly. On terrain that slopes gradually, contour lines are farther apart because it takes longer to reach a change in elevation. Contour lines are drawn at equal changes in elevation, such as every 2, 5, or 10 ft. Elevation is usually labeled at least every fifth contour. Many of the maps described in this chapter include contour lines. Chapter 8 explains contour lines in detail.

Quadrangle Maps

A **quadrangle map** is a map of an area of the Earth’s surface with a grid showing geographic location. Figure 1–8 displays an example of a **US Topo** quadrangle map published by the U.S. Geological Survey (USGS). Quadrangle maps are typically drawn using colors

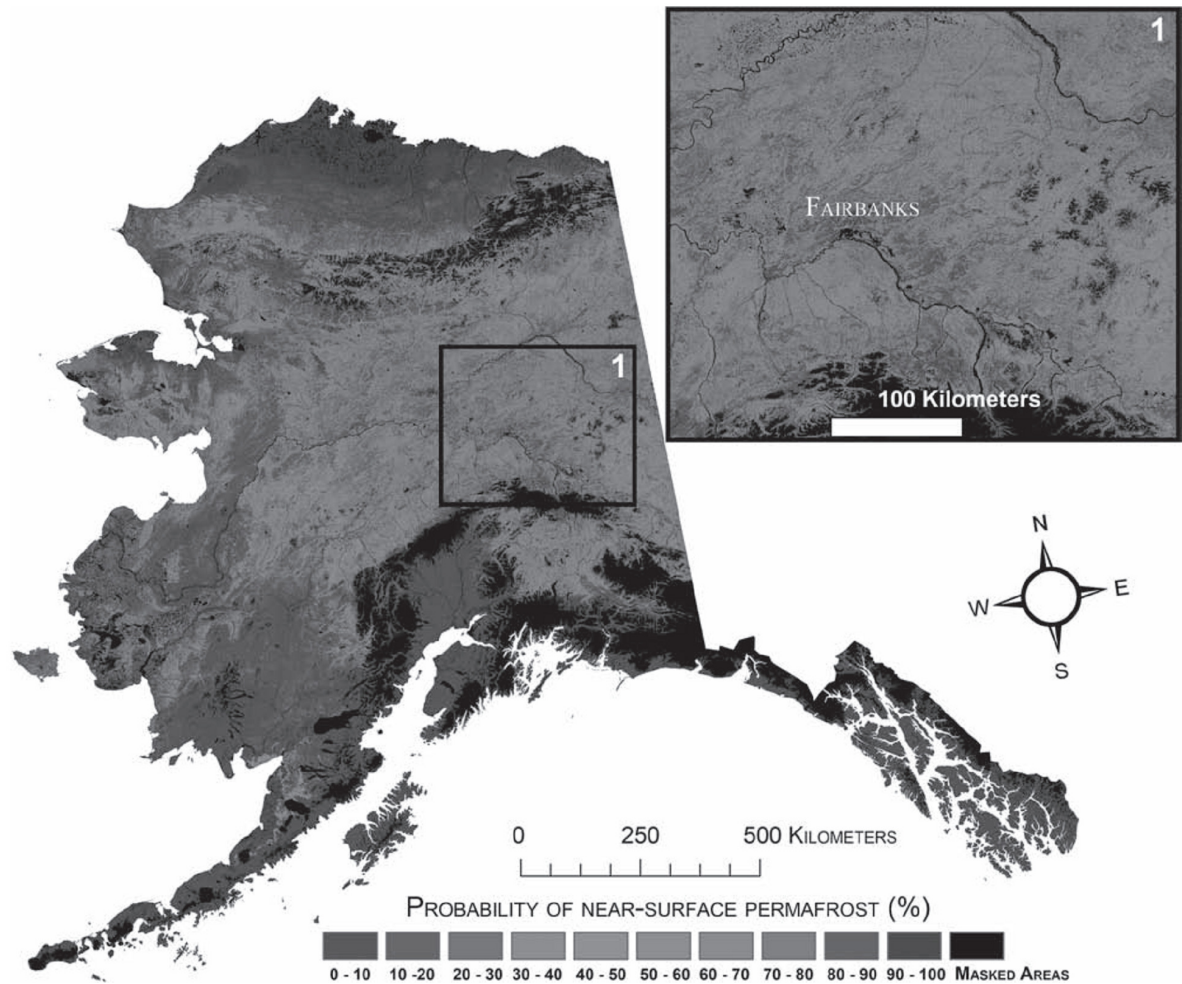


Figure 1-5. A permafrost distribution thematic map of mainland State of Alaska created using satellite images.

(Courtesy of the U.S. Geological Survey)

that represent different map features. Contour lines are often brown, while streams, lakes, and rivers are blue. Woodland features are green, and structures, such as buildings and roads, are usually black. Some quadrangle maps also indicate boundaries of the Public Land Survey System (PLSS) explained in Chapter 9.

Geologic Maps

A **geologic map** describes the location, type, and extent of geologic features such as rock formations and edges of earth movement (see Figure 1-9). A geologic map is usually created by adding geologic information to an existing map, typically, a topographic map. Geologic maps contain a variety of lines, shapes, symbols, and colors. Each color on a geologic map represents a different type and age of rock. Scientists and engineers use geologic maps for many different purposes. The following are some of the data geologic maps help provide:



Figure 1–6. This aerial photograph of the District of Columbia can be used to create a photogrammetric map.

(Courtesy of the U.S. Geological Survey)

- Locations of acceptable building sites or agricultural areas.
- Identification of areas prone to earthquakes, volcanoes, floods, and other dangers.
- Locations of beneficial natural resources such as natural gas, oil, groundwater, precious minerals, and gravel; or dangerous elements such as asbestos.

Military Maps

A **military map** displays information of military importance or that serve a military use. A military map can be used by a soldier in the field and can have information about terrain, concealment, and cover. **Terrain** is the shape and lay of the land. A military map can show a large geographic area useful for military planning. Military maps often display special military symbols that signify military activity. For example, blue symbols represent friendly forces, while red symbols represent enemy forces. Distance on military maps is measured in meters, and angle is measured in mils. A **milliradian**, or **mil**, is a unit of angular measurement approximately equal to 1/6,400 of the circumference of a circle. Military artillery and gun sight settings are expressed in mils. Military maps are also designed to be read in the dark using a red light. Figure 1–10 shows a portion of a military map.

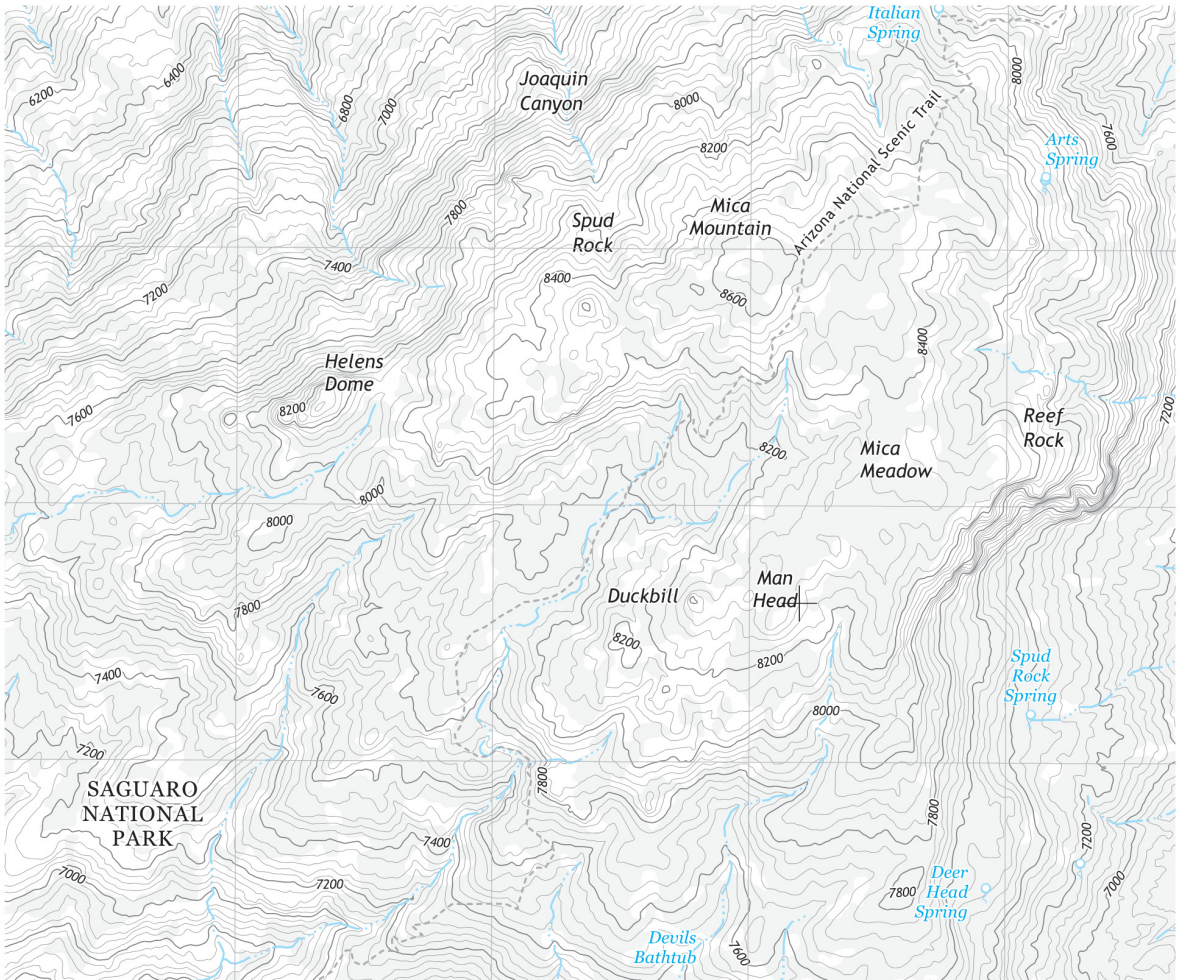


Figure 1-7. A portion of the Mica Mountain, Arizona topographic map.
(Courtesy of the U.S. Geological Survey)

Cadastral Maps

A **cadastral map** is a large-scale map that accurately shows property boundaries and public lands. Cadastral maps are often used for city and county development, operation, and taxation. Figure 1-11 shows an example of a cadastral map.

Hydrographic Maps

A **hydrographic map** accurately shows the boundaries and characteristics of surface waters, or hydrography. Hydrographic maps are used for water and land resource planning, and often include information about drainage, culture, and conditions. Hydrographic maps are typically printed in color. Figure 1-12 provides a sample of a hydrographic map.

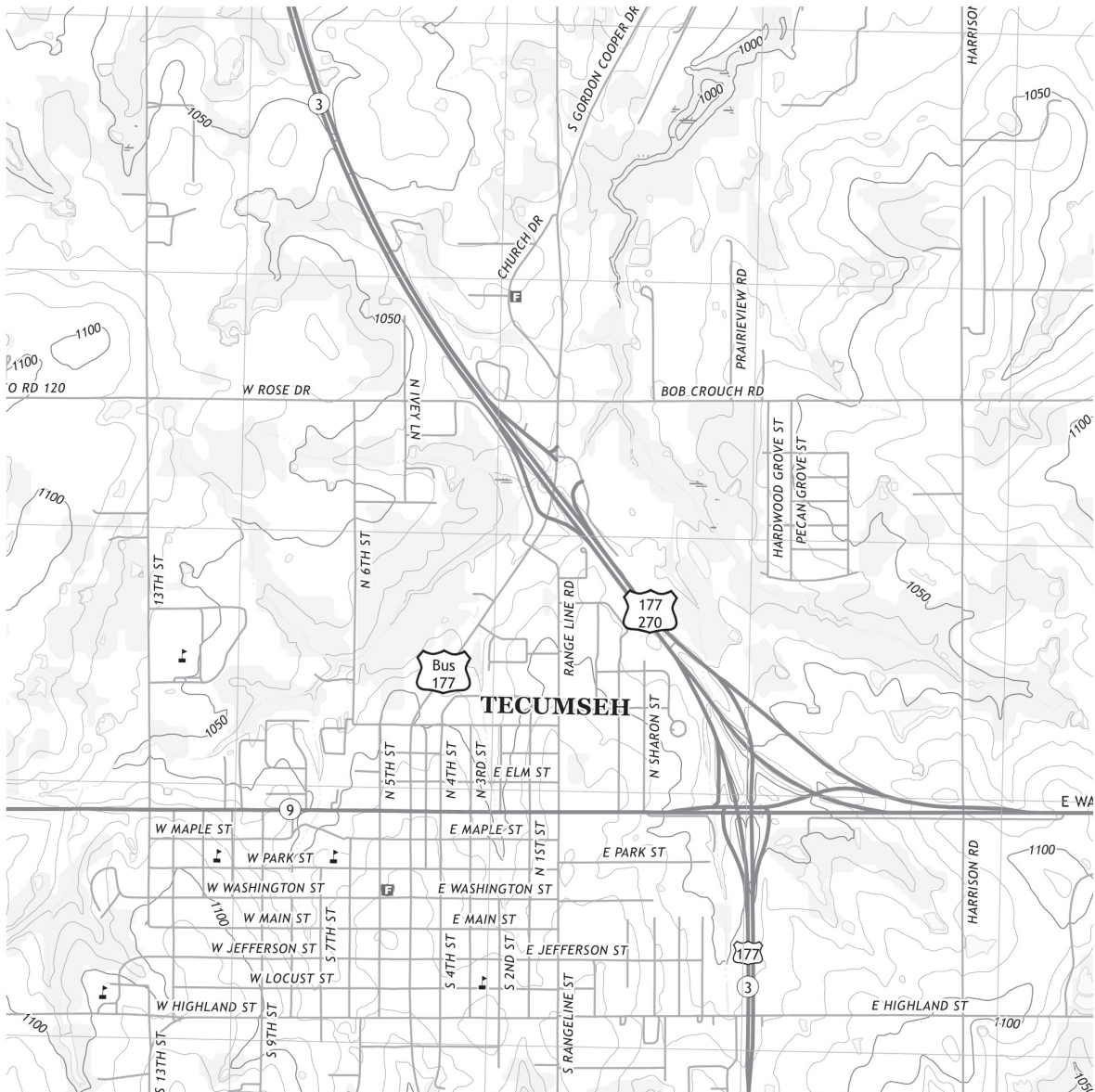


Figure 1-8. A portion of the Shawnee quadrangle map near Tecumseh, Oklahoma.
(Courtesy of the U.S. Geological Survey)

Engineering Maps

An **engineering map** details the layout of an engineering project such as a building construction project. Figure 1-13 shows an example of an environmental engineering map. Engineering maps are unique to each project and application. The following items are regularly found on a variety of engineering maps:

- Contour lines
- Drainage ways
- Existing and proposed structures

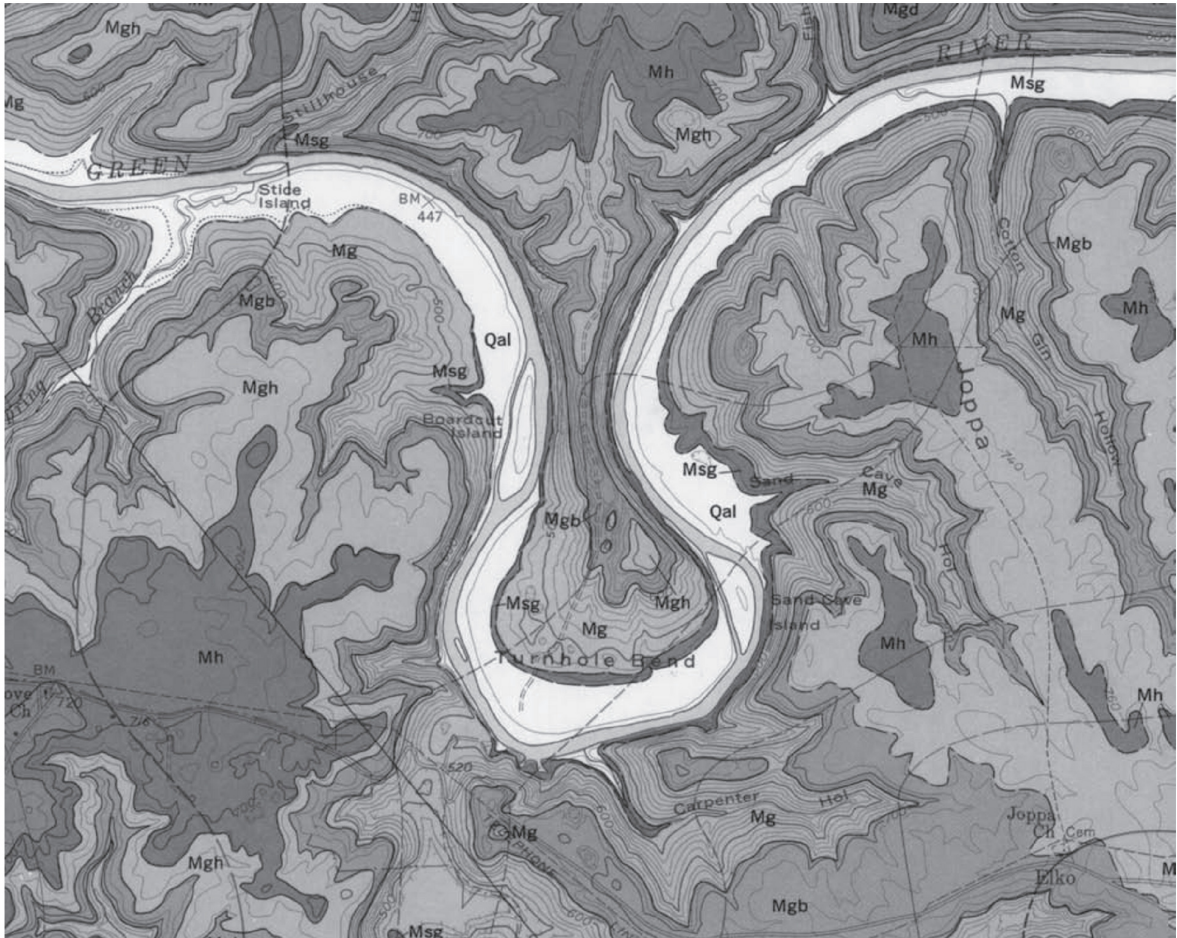


Figure 1-9. Part of the Rhoda, Kentucky quadrangle geologic map.
(Courtesy of the U.S. Geological Survey)

- Landscaping
- Location and size dimensions
- Parking areas
- Property lines and boundaries
- Roads
- Specifications
- Utilities such as water, sewer, electrical power, and natural gas

A site plan is an example of a common engineering map. A **site plan**, also known as a **plot plan**, **plot**, or **plat**, is a drawing that shows an accurate layout of a piece of land. Engineers and developers use site plans to map construction projects. The term plat can refer one or more pieces of land, but is commonly associated with a group of individual sites. Figure 1-14 shows an example of a subdivision plat. A **subdivision** is a tract of land divided into lots. Figure 1-15 shows an example of a residential site plan. Chapter 9 explains site plans in detail.



Figure 1-10. A military map looks very similar to a quadrangle map, but uses different units and displays military significant information, symbols, and colors.

(Courtesy of the U.S. Geological Survey)

Planning Maps

Engineers, developers, and urban and city planners use many different types of maps when designing and maintaining community land use projects and infrastructure. **Infrastructure** is the structures, facilities, and services required for an economy to function such as buildings, roads and bridges, water supply and sewer systems, and power supply and telecommunication systems. All of the maps explained in this chapter can be useful for planning purposes depending on the application. A **planning map** depicts the layout and characteristics of an area for municipal planning purposes. A planning map may have a photogrammetric or topographic base map overlaid with appropriate



Figure 1-11. A portion of a Portland, Oregon cadastral map.
(Courtesy of the City of Portland, Oregon)

information such as zoning boundaries, urban growth boundaries, or population density. A planning map can be combined with hydrographic maps or engineering maps, for example, to show existing conditions and to plan for improvements. Depending on the specific need, planning maps are often produced in color and may be either large or small scale.

Many planning maps, such as the portion of a zoning map shown in Figure 1-16, are generated using GIS technology. A **zoning map** is typically used to layout and categorize districts within a town, city, or state. Chapter 14 is an introduction to GIS.

Nautical Charts

A **nautical chart** is a map used to aid to water navigation (see Figure 1-17). Nautical charts provide information such as water depths, bridge clearances, and the location of overhead cables. Nautical charts also show navigation lanes, lighthouses, beacons, and buoys.



Figure 1–12. A hydrographic map of the contiguous United States.
(Courtesy of the U.S. Geological Survey)

Aeronautical Charts

An **aeronautical chart** is a map used to aid air travel (see Figure 1–18). Aeronautical charts indicate important features of land such as mountains and outstanding landmarks in a format similar to a detailed physical map. Contour lines are regularly provided with 200–1,000-ft. intervals. Aeronautical charts provide comprehensive information regarding air routes, airport locations, types of air traffic, radio aids to navigation, and maximum elevation of features.

Digital Models

A **digital elevation model (DEM)** typically refers to a raster image model created from a collection of 3-D points showing bare surfaces of land, without natural vegetation and built structures. Figure 1–19 shows a 3-D DEM of Mount St. Helens in Washington State before and after the May 18, 1980, eruption. A **digital surface model (DSM)** typically refers to a raster image model that shows land with natural and built surface features such as vegetation and structures. DEM and DSM data points can be collected using ground surveying; though remote sensing, typically from aircraft or satellites, is most often associated with DEM and DSM data collection. **Remote sensing** refers to the detection of information about an object or experience, without actually contacting the object or experience. Chapter 5 includes additional information about remote sensing.

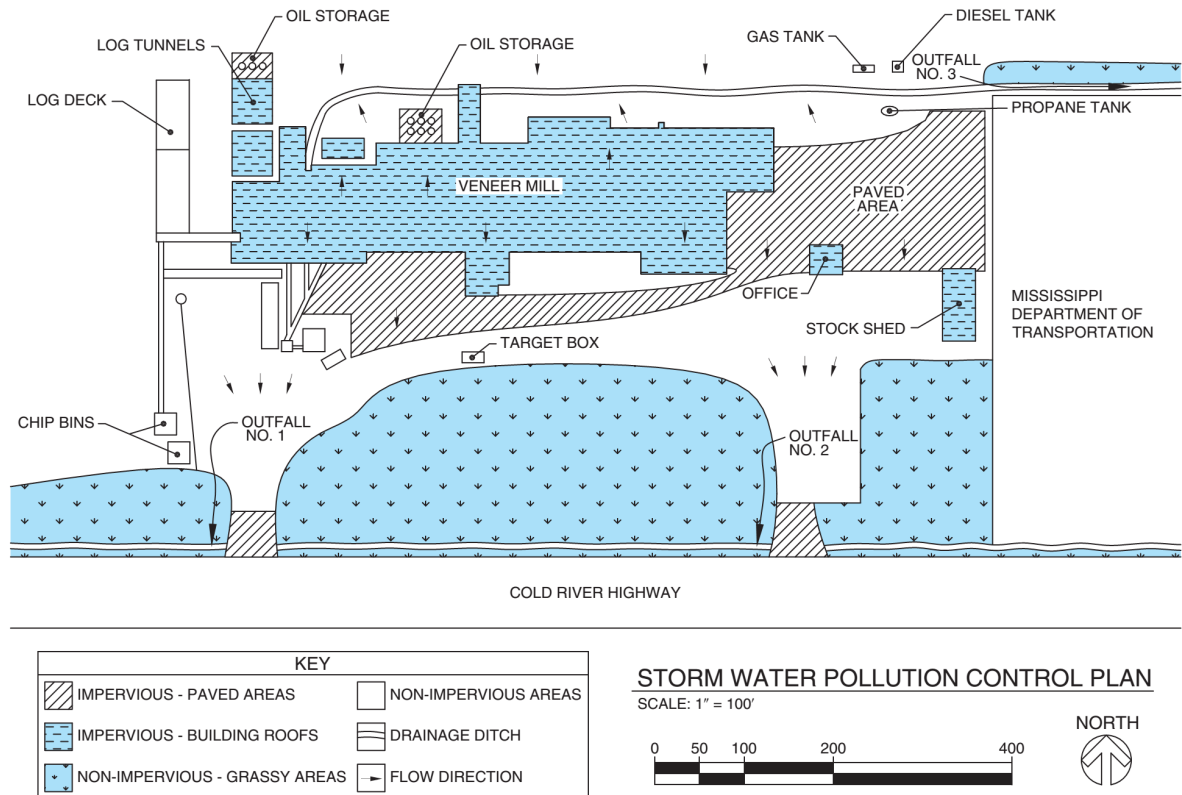


Figure 1-13. A storm water pollution control site plan showing impervious and non-impervious surfaces, and the mapping of the location and direction of storm water flow.

DEM and DSM data can be used to produce a variety of realistic and easily understandable maps and images, such as the thematic map shown in Figure 1-5. Different viewpoints of a site can be observed with the use of specialized computer software, and the vertical scale can be magnified to display elevation changes at sites that are relatively flat. Additional information and graphics can be applied to digital models including photorealistic rendering and topographic map overlays (see Figure 1-20). DEMs are helpful for a variety of applications such as slope analysis and determining hydrographic boundaries; and planning of highways, subdivisions, and underground utilities that rely on gravity flow. Engineers analyze DEMs to find flaws or problem areas during the design of, and before building, a project.

Though sometimes used as a synonym for DEM, a **digital terrain model (DTM)** typically refers to a vector graphic model created from a collection of 3-D points showing terrain and features that define a change in slope such as a stream or ridge, or the edge of a wall or road. A DTM is generally described as a model of the existing terrain that is developed from elevation data collected in reference to a coordinate system. As explained later in this textbook, data points collected during a conventional ground survey can be imported into a CADD system to create a DTM for civil engineering design and analysis.

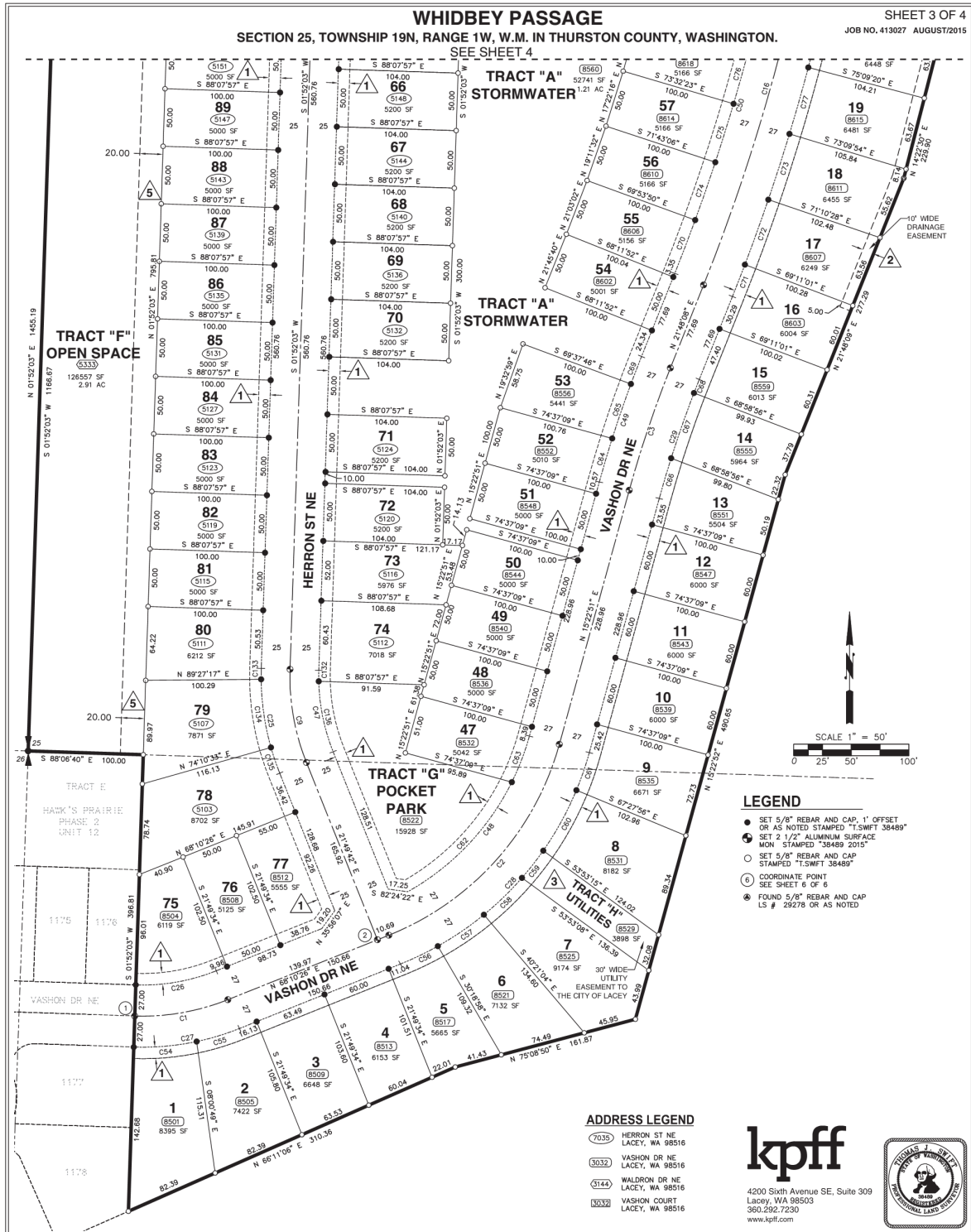


Figure 1-14. A subdivision plat required for the development of a residential housing subdivision.
(Courtesy of KPFF Consulting Engineers)

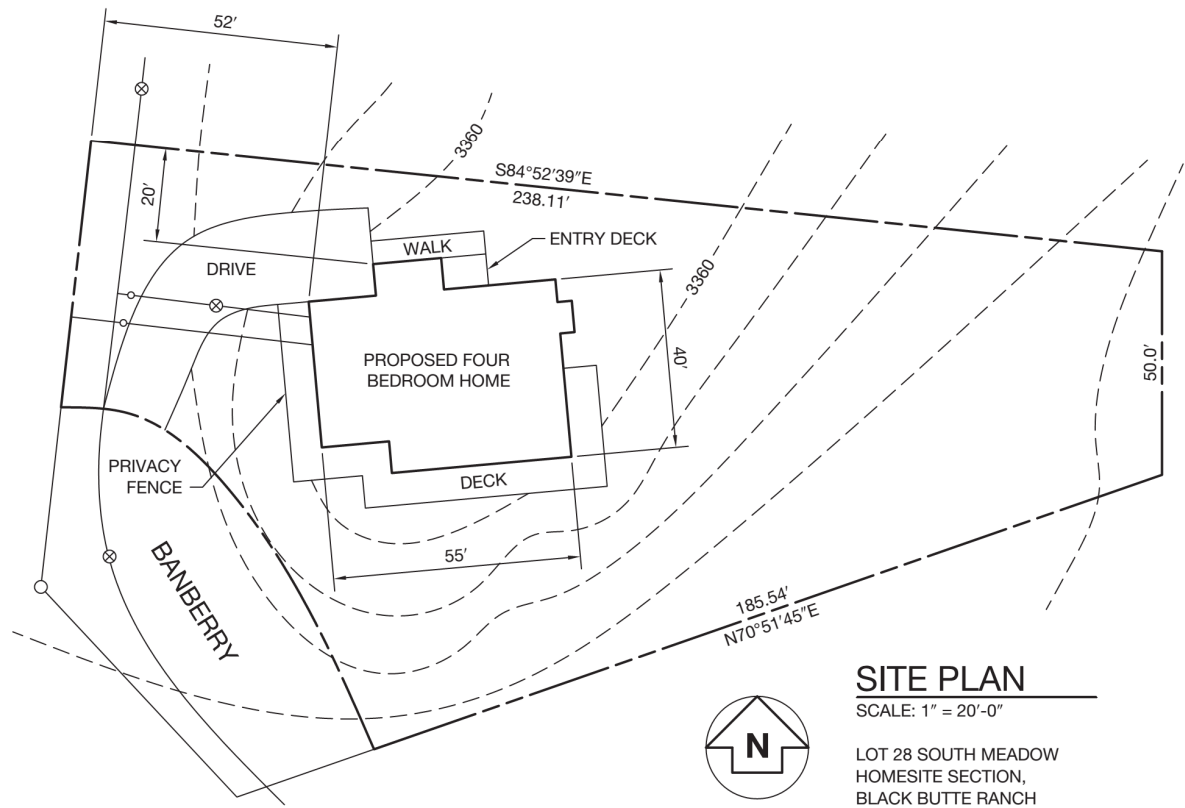


Figure 1-15. A residential building site plan.

The Design and Drafting Process

Civil engineering companies and agencies are often involved in all phases of a construction project, especially the design and drafting necessary to document the project. Depending on the size and capabilities of the company or agency and the scope of the project, civil engineering firms create drawings internally or contract with other firms that specialize in certain aspects of the project. The civil engineering design and drafting process involves several stages, from determining the general extents of the project to completing the design.

Surveying is an early phase of the civil engineering design process, and often continues throughout a project. Surveying is often contracted to licensed surveyors. **Surveyors** provide a map file of the job site from which civil designers and drafters develop drawings. Chapter 5 explains more about surveying. Departments within the civil engineering firm then work on site preparation, street and parking layout, earthwork grading and drainage, and foundation and structural work. Architectural design and drawings might be handled by the civil engineering firm or contracted to an architectural company. Architects may be given appropriate base drawings from which to work such as site plans, contour maps, road layouts, and structural drawings.

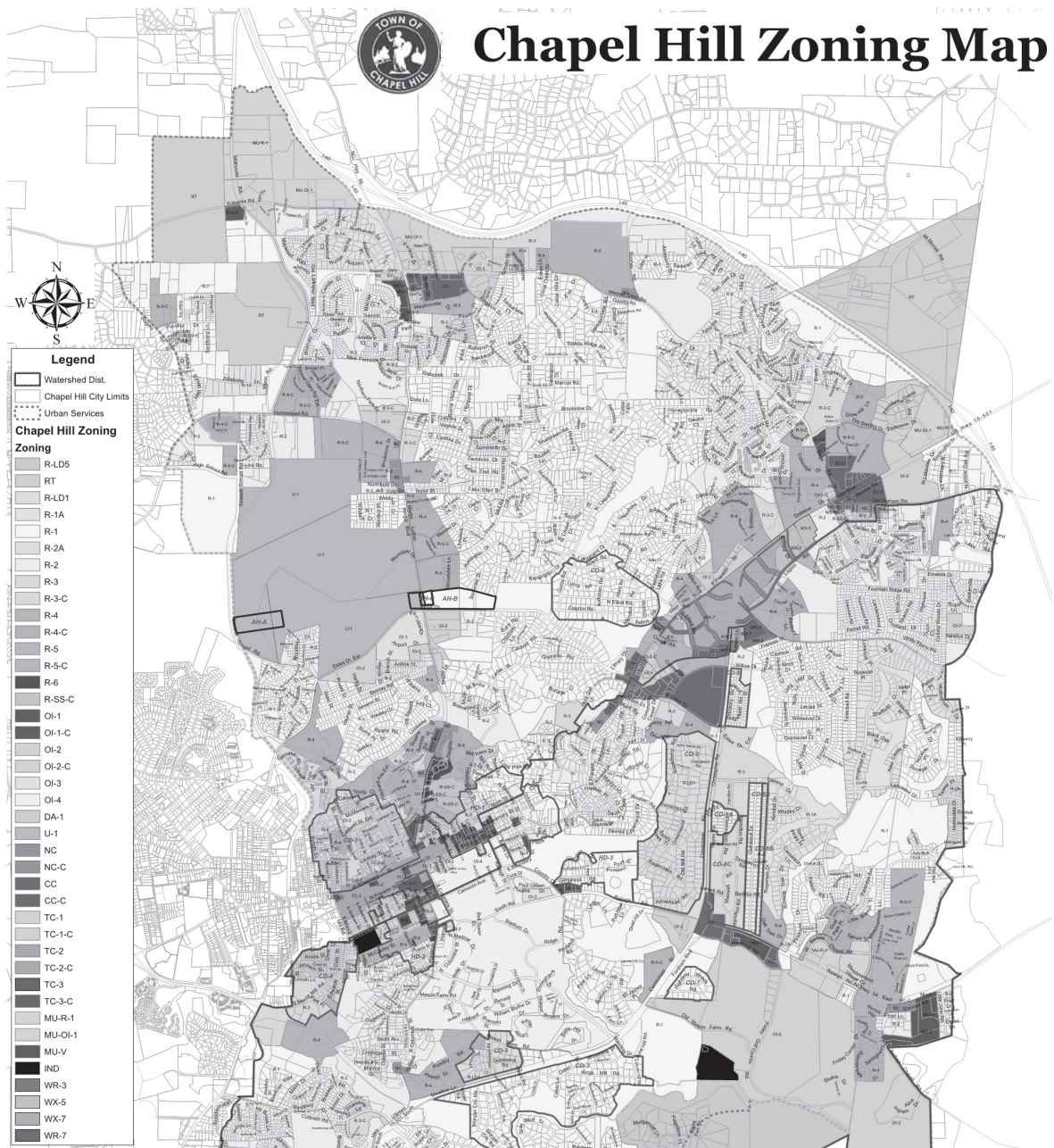


Figure 1-16. A portion of a Chapel Hill, North Carolina zoning map. A zoning map is an example of a common planning map.

(Courtesy of the Town of Chapel Hill, North Carolina)

Projects involving mechanical, piping, and electrical work such as waterworks, sewage treatment, and power generation may require specialized design and engineering. These aspects of a project might be contracted to engineering companies that focus in these

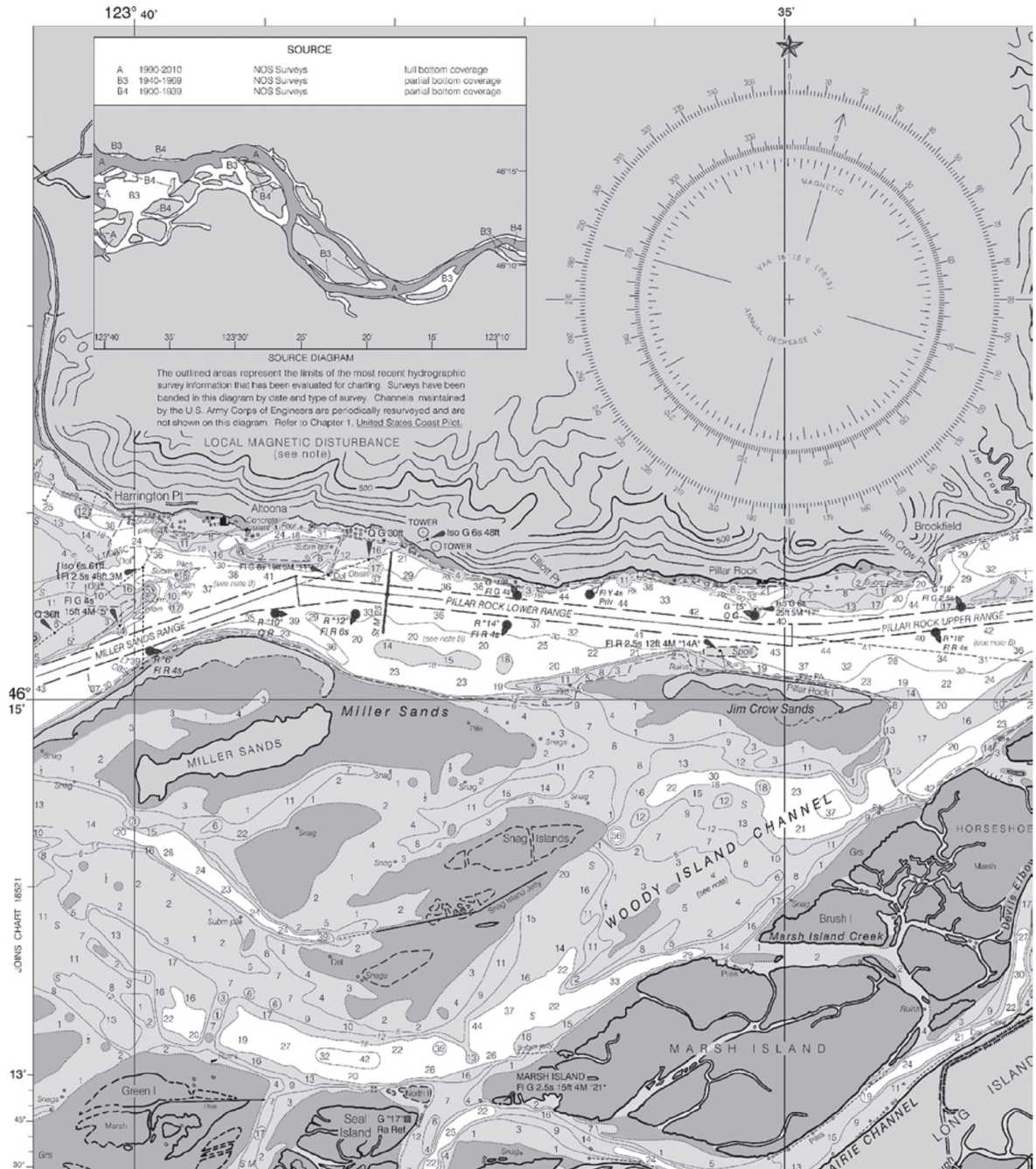


Figure 1-17. A part of the Columbia River nautical chart.
(Courtesy of the Office of Coast Survey, National Oceanic and Atmospheric Administration)

disciplines. Final stages of a project may involve finished site preparation and landscape design. This aspect of a project may be contracted to landscape architects. Each stage of the civil engineering design and drafting process results in specific plan, cross section, profile, and/or detail drawings.

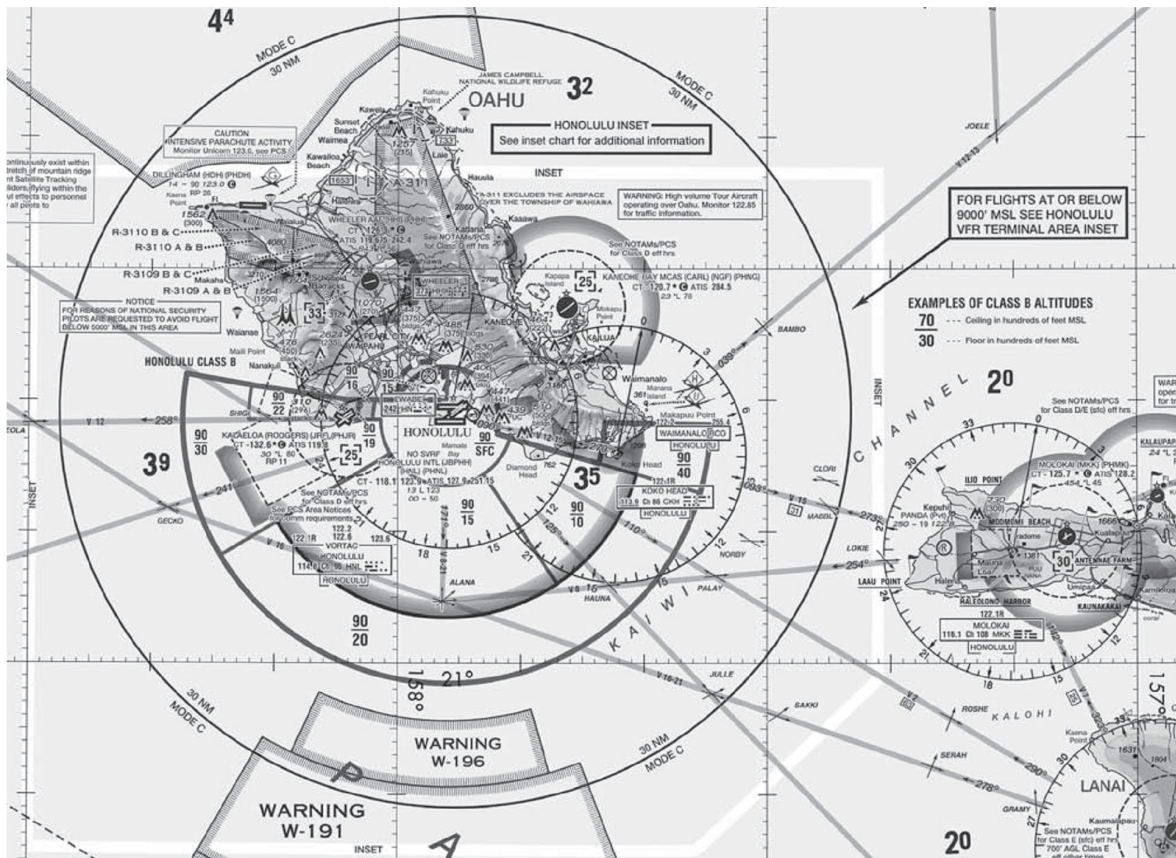
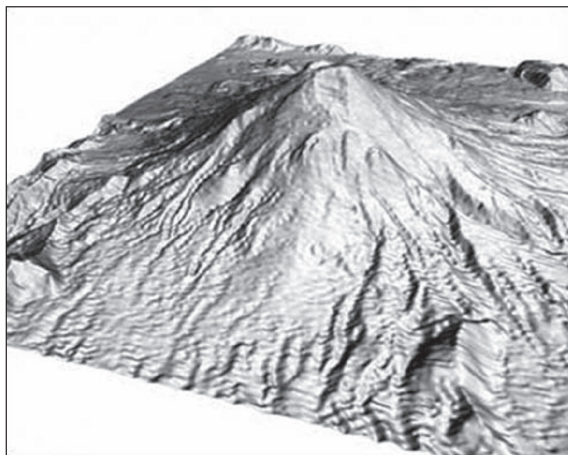
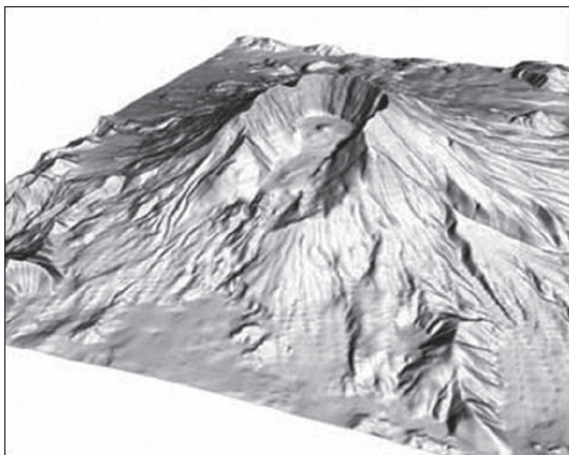


Figure 1-18. A part of the Hawaiian Islands aeronautical chart.
(Courtesy of the National Aeronautical Charting Office, Federal Aviation Administration)



Before



After

Figure 1-19. A 3-D DEM of Mt. St. Helens in Washington State before and after the May 18, 1980, eruption.

(Courtesy of the U.S. Geological Survey)

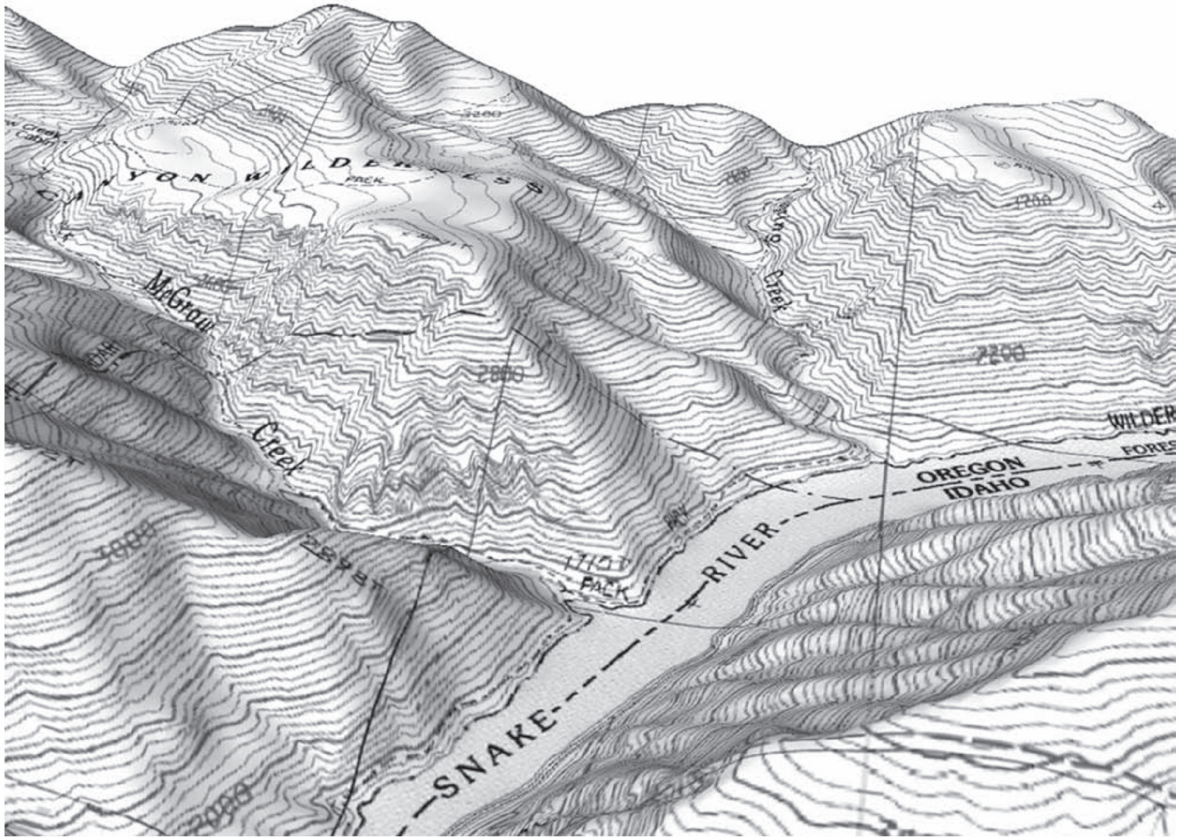


Figure 1-20. A 3-D DEM of a portion of the Snake River between the states of Oregon and Idaho. This DEM includes a topographic map overlay.
(Courtesy of the U.S. Geological Survey)

Plan Drawings

A **plan view**, or **plan**, is a view of an area looking down on the area as projected onto a horizontal plane. Plan views illustrate aspects of a project such as property lines, roads, structures, utilities, and landscaping. A variety of plan drawings may be created depending on the size and complexity of a project. Maps and site plans are some of the first drawings created for a project.

A **vicinity map** places a project site within a large area, such as several square miles, and provides an overview of the site relative to the surrounding area (see Figure 1-21). A site plan is drawn at a larger scale than the vicinity map, and depicts the overall scope of the project. Several site plans may be included in a set of drawings, each illustrating a specific element of the design. Figure 1-22 shows an example of a site plan for a subdivision.

Cross Section and Profile Drawings

Once plan drawings are available, cross section and profile drawings are created to show the side view, or elevation, of plan view features. A **cross section view**, or **cross section**, is a view that cuts through

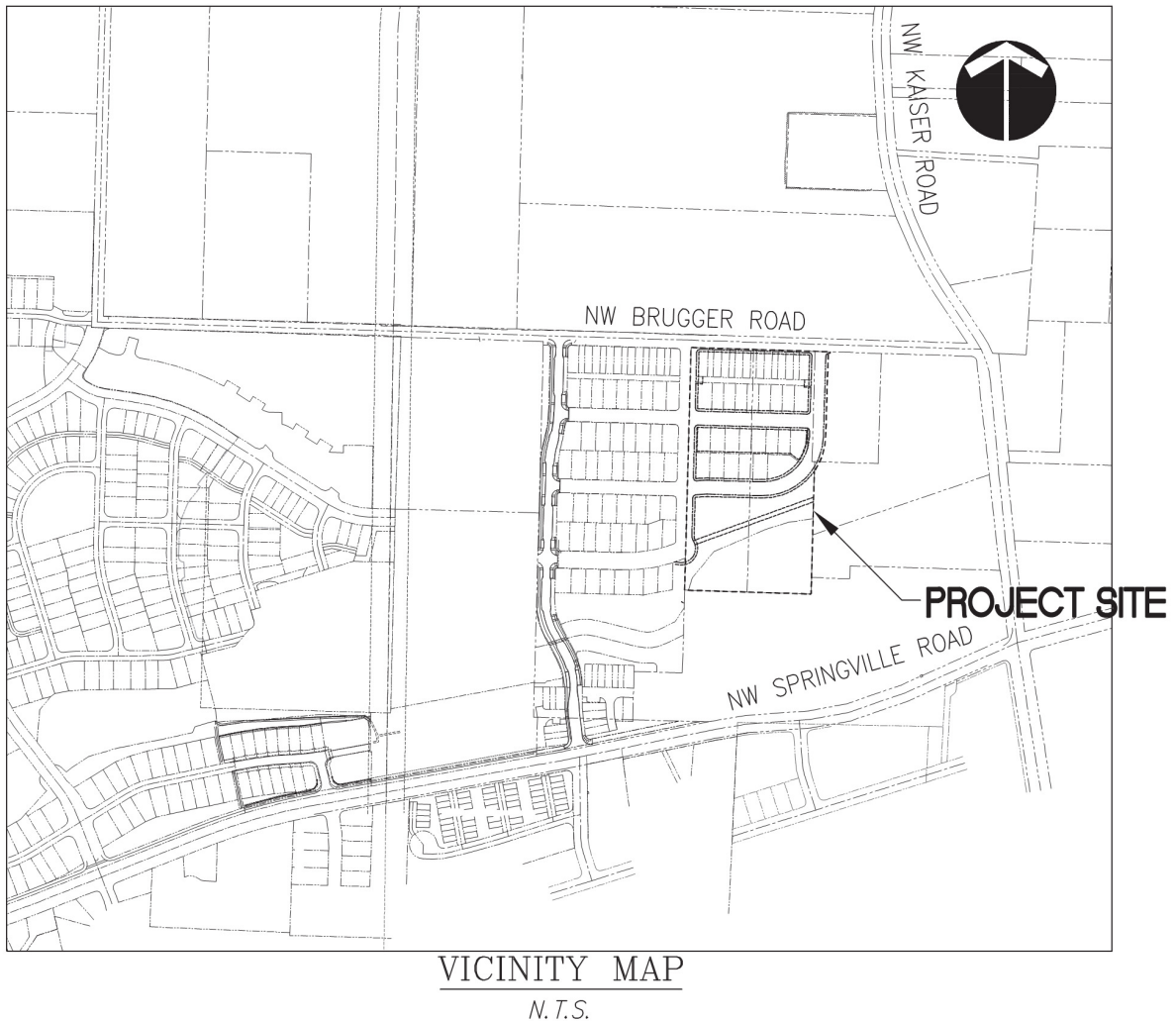


Figure 1-21. A vicinity map places a project site within a large area and provides an overview of the site relative to the surrounding area.

(Courtesy of Otak, Inc.)

an area to show detail that cannot be clearly identified in plan view. The terms cross section and section are often used interchangeably. Technically, a cross section cuts completely across a feature, while a section cuts through a feature partially or completely. A **profile** is a cross section of a portion of land, or along the length of a linear feature such as a road, sewer line, power line, or stream. A profile normally has horizontal and vertical scales that are different (see Figure 1-23). Chapter 11 describes profiles in detail.

A **cutting-plane line** is a line drawn on a plan view to show the location of a cross section cut. A cutting-plane line usually terminates with arrowheads or other symbols that point toward the cutting plane, indicating the line of sight when looking at the cross section. Cutting-plane lines often include information to help key the plan view to the cross section in a set of drawings. Figure 1-24 displays a portion of the site plan shown in Figure 1-22. The letter

in the top half of the cutting-plane line symbol is the identification for the section, and the information in the lower half of the symbol indicates the sheet on which the section is shown. The sheets in a set of drawings for a project are numbered sequentially. To find section A-A in Figure 1–24, go to sheet C1.2 of the drawing set. Figure 1–25 shows section A-A.

A **typical cross section** is common to any location along the feature such as the street shown in Figure 1–26. Therefore, a cutting-plane line for the section is not shown on the plan drawing. Specific cross sections may be shown if features such as drains and underground utilities are required. A section will have a certain scale, or may be indicated as not to scale (NTS) as shown in Figure 1–26. Chapter 12 explains cross sections in detail.

Detail Drawings

A **detail drawing**, or **detail**, is typically an enlarged view created to describe features not shown on other drawings. Details can be created for any construction feature. Details normally specify standards that govern the project, and are used to guide construction. Most civil engineering companies and agencies have large libraries of standard

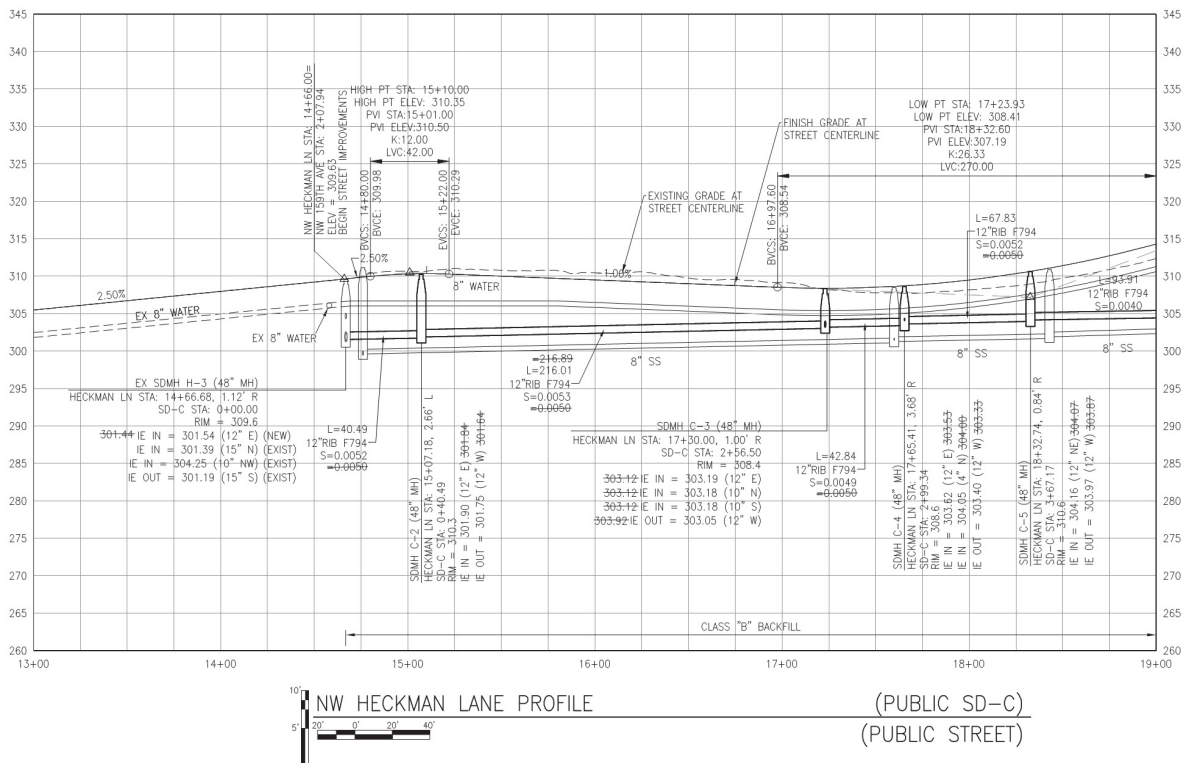


Figure 1-23. A profile is a section that is cut along the length of a linear feature, such as this street, and normally has different horizontal and vertical scales.

(Courtesy of Otak, Inc.)

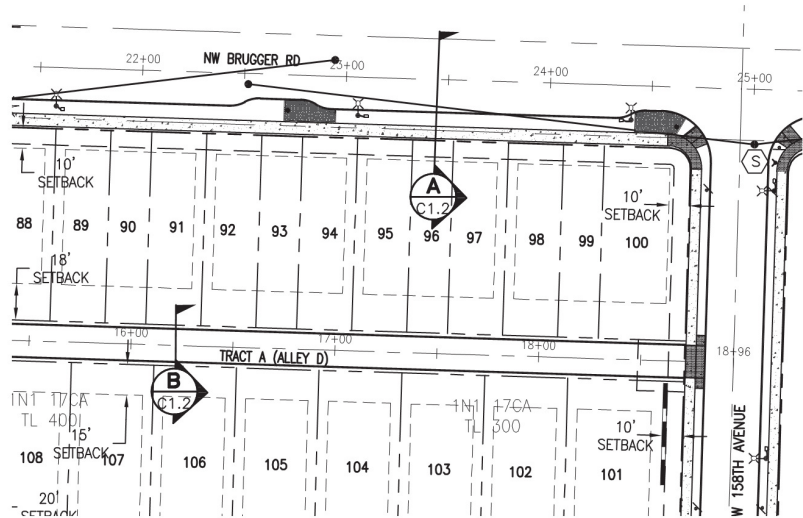
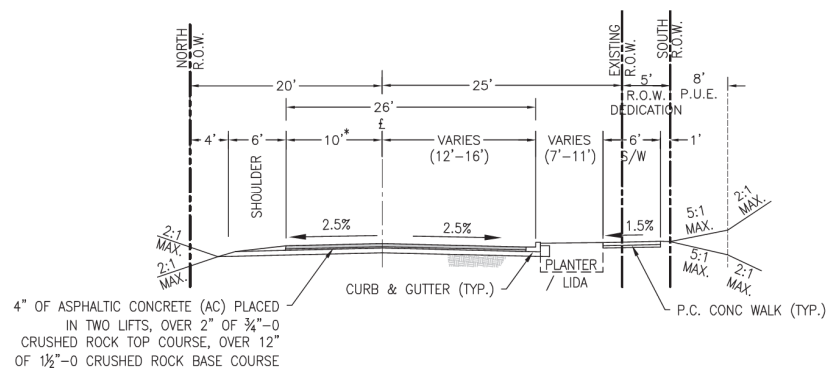


Figure 1-24. Cutting-plane line symbols shown on a plan view. Sections A-A and B-B are shown on sheet C1.2, and the views are to the right.
(Courtesy of Otak, Inc.)



NW BRUGGER ROAD
SECTION A-A
WASHINGTON COUNTY NR-4
SHARED PARKING / BICYCLE LANES

* NOTE: LEFT SIDE OF BRUGGER ROAD TO BE CONSTRUCTED UNDER SEPARATE PERMIT & CONTRACT (NORTH BETHANY RIDGE FACILITY PERMIT). CONSTRUCTION OF THIS SIDE OF ROAD SHOWN ON THESE PLANS IN EVENT NORTH BETHANY RIDGE IS NOT COMPLETE.
 16' O/S TOC RT = $\text{CL} + 0.05$
 12' O/S TOC RT = $\text{CL} + 0.15$

Figure 1-25. This is section A-A, cut on sheet C1.1 and shown on sheet C1.2.
(Courtesy of Otak, Inc.)

details. Details may be shown on one of the plan sheets if they are common features and the subject of a specific plan. If a detail is not a typical construction standard, it may be shown on plan sheets, cross sections, or with other details. Figure 1-27 shows an example of a detail drawing.

As-Built Drawings

An **as-built survey** is preformed after a construction project is finished to identify final construction, including improvements and structures created during construction. As-built surveys provide the data required to create as-built drawings. An **as-built drawing**, also known as an **as-built**, is drawn after a construction project is finished to document final construction. As-builts can reveal changes made during construction that differ from the design shown in the construction documents. As-built drawings are also referenced for maintenance and operations, and future alterations to a structure. As-built changes are often drawn by the contractor, and shown in red.

Drafting Standards

Most industries have established standards. **Standards** are a set of technical definitions and guidelines that specify requirements, techniques, and operating procedures. Standards promote safety, reliability, productivity, and efficiency. A **code** is a standard that one or more governmental bodies adopts and has the force of law. Standards are considered voluntary because they serve as guidelines. However, successful engineering companies and agencies implement and strictly adhere to nationally and internationally recognized drafting standards. Standards become mandatory when incorporated into a business contract or regulations.

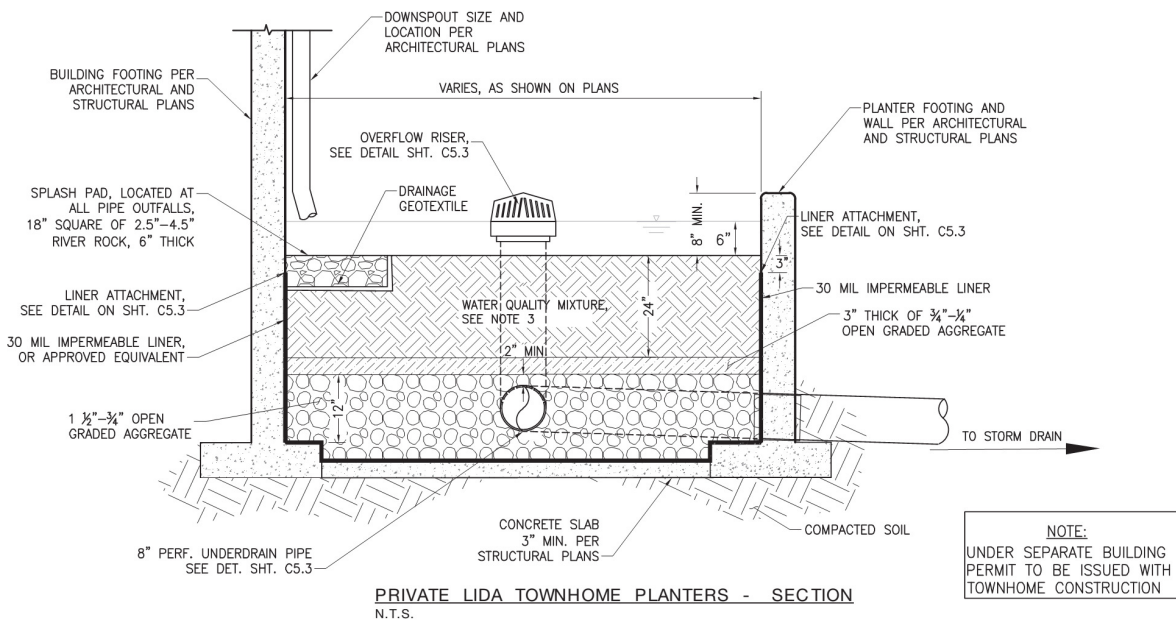
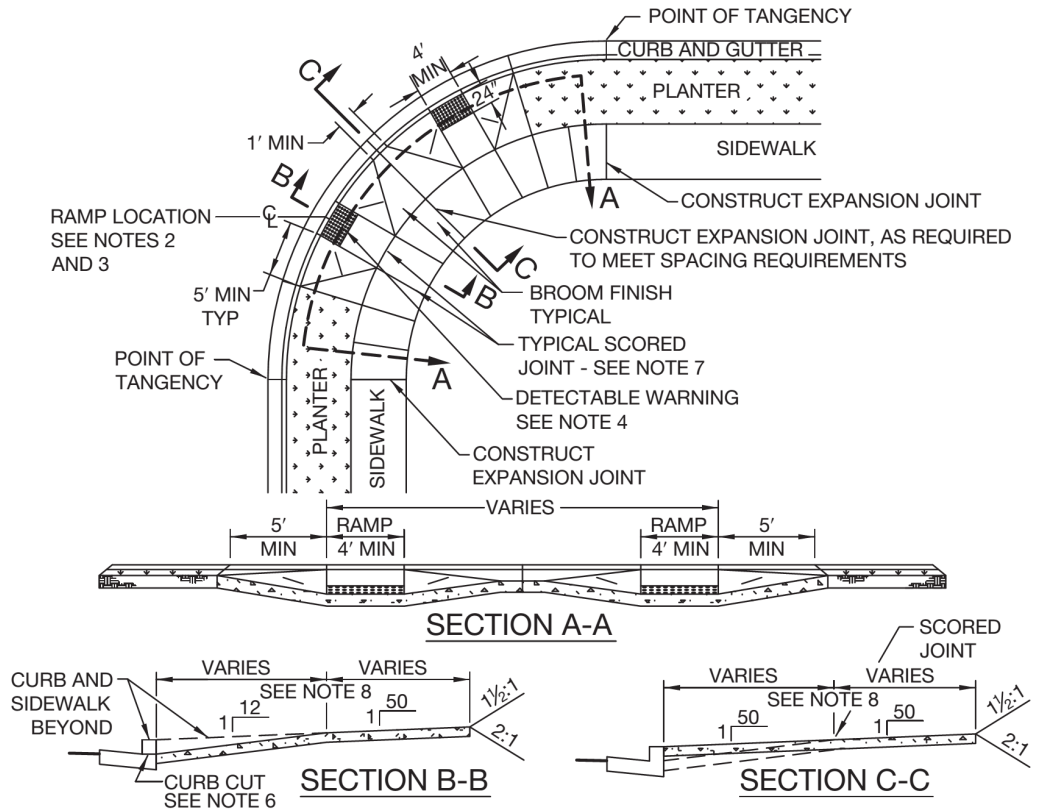


Figure 1–26. A typical cross section common to any townhome built in the subdivision. This section shows the construction of a low impact development approach (LIDA) storm water pollution control system.

(Courtesy of Otak, Inc.)



NOTES:

1. Sidewalk ramp shall meet *ADA Standards*.
2. Engineer shall prepare a site-specific drawing for each ramp, accepting full responsibility for correcting all unacceptable ramp construction resulting from applying this drawing "as is."
3. Each ramp shall be located relative to crosswalk or stop line.
4. Detectable warning shall be 24 inches long in the direction of travel and full width of the ramp, made of concrete imbedded yellow tiles, that have truncated domes aligned on a square grid with its gridlines parallel and perpendicular to the centerline of the ramp, from the approved list in the *Engineering Design Manual*, Sec 210.10.
5. Concrete shall have a compressive strength of 4,000 psi at 28 days.
6. Bevel the curb cut from gutter to back of curb at 8.33% (1:12).
7. Score at grade changes, surface texture changes and at other points shown. Edges shall be shined.
8. For sidewalk and planter strip widths and sidewalk panel dimensions, see *Beaverton Standard Dwg 215*.
9. Curb inlet or catch basin shall not be allowed in front of sidewalk ramp.
10. A single ramp may be used at "T" intersections at the locations shown in the diagram in the *Engineering Design Manual*, Sec 210.10.

STANDARD SIDEWALK RAMP WITH PLANTER STRIP

Figure 1-27. This detail illustrates the construction standards for sidewalk ramps with a planter strip to be used in the subdivision street system.

(Courtesy of PACE Engineers, Inc.)

One of the most important concepts for a new drafter to understand is the role that standards play in the design and drafting process. Standards are important for engineering communication because they serve as a common language. Standardized procedures result

in lower costs, fewer errors, and simplified training. The cleaner and more accurate drawings are when sent out for bids, permitting, and construction, the greater the potential is for saving time and money.

Drawing standards apply to most settings and procedures, from the name assigned to a CADD file to the appearance of symbols and text on a drawing. Though standards vary in content, the most important point is that standards exist and are understood and used by all design and drafting personnel. When you follow drawing standards, drawings are consistent, you become more productive, and projects function more efficiently. Standards are generally defined by professional organizations, companies, clients, government agencies, and projects.

Professional Organization Standards

Members of professional associations, such as those identified in this chapter, develop or have a strong influence on national and international design and drafting standards and practices. The American Society of Mechanical Engineers (ASME) is an accredited standards developing organization that meets American National Standards Institute (ANSI) requirements. Codes and standards developed under an accredited program can be designated as American National Standards. Many ASME drafting standards apply to drawings prepared in the manufacturing industry or specialized engineering disciplines. However, several ASME standards, such as **ASME Y14.2 Line Conventions and Lettering**, provide general drafting standards that can be adapted to any field. For more information about ASME standards, go to www.asme.org.

The International Organization for Standardization (ISO) develops and maintains an extensive list of internationally recognized standards and related documents. ISO standards are based on the opinions of experts in ISO technical committees. Many ISO drafting standards apply to a specific discipline. The **93: Civil engineering** series are civil engineering standards. The **01.100.30: Construction drawings** standards are construction, including civil engineering, drawing standards. Several ISO standards, such as many of the standards found in the **01.100: Technical drawings** series, offer fundamental drafting principles that can be applied to any field. For more information about ISO standards, go to www.iso.org.

The United States National CAD Standard (NCS) is a set of standards intended to simplify and increase the efficiency and accuracy of CADD data exchange. The NCS was developed by several national organizations, and focuses on architecture, engineering, and construction (AEC) projects. The American Institute of Architects (AIA), Construction Specifications Institute (CSI), and the National Institute of Building Sciences (NIBS) contribute to the NCS. The NCS includes four major components:

- AIA CAD Layer Guidelines
- Uniform Drawing System (UDS)
- BIM Implementation
- Plotting Guidelines

Chapter 2 explains more about the NCS. For additional information about the NCS, go to www.nationalcadstandard.org or www.nibs.org.

The National Council for Advanced Manufacturing (NACFAM) publishes the ***National Skill Standards for Computer-Aided Drafting and Design***. This publication provides the skills needed for beginner CADD users. While this standard is not related specifically to civil drafting, it contains valuable content for new CADD drafters, professionals, and educators. For more information about NACFAM, go to www.nacfam.org.

Company Standards

Engineering firms adopt standards published by professional organizations, and/or apply client, government, and project standards. Companies also create their own standards as an element of the business process, and in an attempt to save time and expense. Examples of company standards are methods of saving and storing CADD data; plotting procedures; systems for transferring files to vendors; and libraries of symbols, cross sections, and details. Company standards are often proprietary and may or may not be created based on nationally or internationally recognized standards.

Client Standards

Company standards often reflect the clients with which the company works. The **client** is the individual or organization for which a project is developed. A client can be a private interest, such as a landowner or developer, or a government municipality. Client standards are often reflected in detail drawings representing methods of layout, design, and construction.

Government Standards

City, county, state, and federal codes and details typically apply to many aspects of a civil engineering project. Government codes and details must be adhered to even if professional organization and company drafting standards are available. Government standards apply when required to all projects, even if the government is not the client. Municipalities and government agencies usually have libraries of symbols, details, cross sections, and other drawing files that are used directly in a set of drawings for a project. A CADD drafter must be able to locate and use these files properly.

Project Standards

Project standards may include a combination of professional organization, company, client, and government standards. Project standards are the final documents that are used to design and build a project. Depending on the size and scope of the project, a document with a title such as ***Project Specifications*** may be printed and made

available for reference. A **specification** is an exact statement describing the characteristics of a particular aspect of a project.

Checking Drawing Standards

Prior to the release of drawings for bids and/or construction permitting, it is important that drawings go through a final check for adherence to applicable standards. **Standards checking** is a procedure by which drawings are checked against a base standards drawing that contains up-to-date drawing, design, and construction standards for a specific discipline or trade. CADD software often includes routines that allow the user to put any drawing or set of drawings through a standards check before the drawings are sent on to the next project phase. Software-based standards checking usually involves opening the drawing to be checked and opening the standards drawings to be used in the checking process. The software may automatically change items not up to standard or mark them for change by the CADD user.

Workplace Ethics

Ethics are rules and principles that define right and wrong conduct. A **code of ethics** is a formal document that states an organization's values and the rules and principles that employees are expected to follow. In general, a code of ethics contains the following main elements:

- Be dependable
- Obey the laws
- Be honest
- Have integrity
- Treat others with respect
- Build teamwork through trust
- Be a good citizen
- Have good customer relations

Intellectual Property Rights

The success of a company often relies on the integrity of its employees. Products are often the result of years of research, engineering, and development. This is referred to as the **intellectual property** of the company. Protection of intellectual property can be critical to the success of the company in a competitive economy. This is one reason why it is very important for employees to help protect design ideas and trade secrets. You will often find proprietary notes on drawings that inform employees and communicate to the outside world that the information contained in the drawings is the property of the company and cannot be used by others without permission.

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Define the following terms.

1-1 Civil engineering

1-2 Civil drafting

1-3 Map

1-4 Cartography

1-5 Legend

1-6 Scale

1-7 Political map

1-8 Photogrammetry

1-9 Contour line

1-10 Terrain

1-11 Cadastral map

1-12 Site plan

1-13 Digital elevation model (DEM)

1-14 Plan view

1-15 Cross section

1-16 Profile

1-17 Detail drawing

1-18 Standards

1-19 Code

1-20 Ethics

Part 2

Choose the response that best describes each statement.

1-21 An instrument with a system of ordered marks at fixed intervals used for measurement is called a:

- a. Title block
- b. Scale
- c. Legend
- d. Digital terrain model (DTM)

1-22 Small-scale maps that display the physical features of an area such as differences in elevation and bodies of water are called:

- a. Political maps
- b. Cadastral maps
- c. Geologic maps
- d. Physical maps

- 1-23** Aerial photos taken at certain intervals and controlled by base stations on the Earth's surface are used to create:
- Contour lines
 - Cutting-plane lines
 - Photogrammetric maps
 - Detail drawings
- 1-24** Maps that accurately show the shape of the Earth using contour lines are called:
- Photogrammetric maps
 - Topographic maps
 - Digital terrain models
 - Geographic maps
- 1-25** Maps that describe the location, type, and extent of geologic features such as rock formations and edges of earth movement, are called:
- Charts
 - Geographical maps
 - Geologic maps
 - Topographic maps
- 1-26** Maps that show the boundaries and characteristics of surface waters, or hydrography, are called:
- Environmental maps
 - Nautical charts
 - Cadastral maps
 - Hydrographic maps
- 1-27** Maps that detail the layout of a construction project are called:
- Thematic maps
 - Cadastral maps
 - Engineering maps
 - Topographic maps
- 1-28** A view of an area looking down on the area as projected onto a horizontal plane is called a:
- Detail view
 - Vicinity map
 - Profile
 - Plan view

- 1-29** A cross section of a portion of land, or along the length of a linear feature such as a road, sewer line, power line, or stream is called a:
- a. Geologic map
 - b. Profile
 - c. Digital elevation model (DEM)
 - d. Cutting-plane line

- 1-30** A standard that one or more governmental bodies adopts and has the force of law is called a:
- a. Code
 - b. Client standard
 - c. CADD standard
 - d. Detail

PROBLEMS

Follow the specific instructions to complete each problem.

- P1-1** Describe five examples of civil engineering projects.
- P1-2** Describe five programs and activities sponsored by the American Design Drafting Association/American Digital Design Association (ADDA).
- P1-3** Classify the type of map shown in Figure P1-3. Describe how you came to your conclusion.



Figure P1-3.
(Courtesy of the U.S. Geological Survey)

P1-4 Classify the type of map shown Figure P1-4. Describe how you came to your conclusion.



Figure P1-4
(Courtesy of the U.S. Geological Survey)

P1-5 Classify the type of map shown in Figure P1-5. Describe how you came to your conclusion.

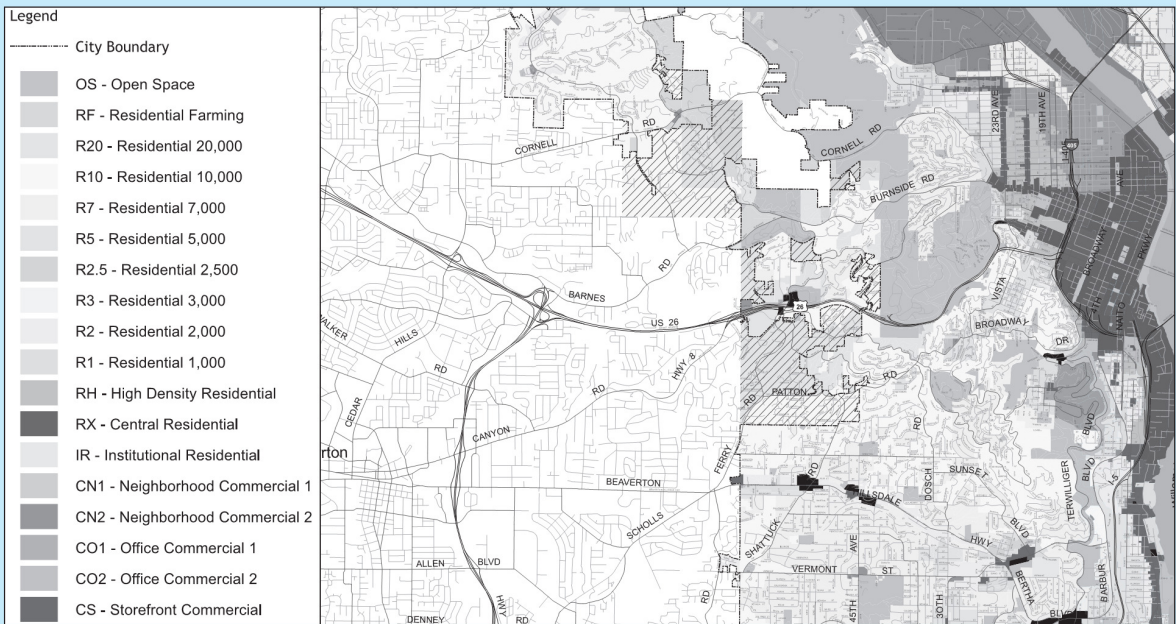


Figure P1-5.
(Courtesy of the City of Portland, Oregon)

P1-6 Interview your drafting instructor or supervisor to determine what type of drawing standards exist at your school or company. Write the standards down and keep them with you as you learn civil drafting technology. Make notes as you progress through this textbook on how you use these standards. Note how you could change the standards to reduce costs and improve productivity.

P1-7 Research and write a report of approximately 250 words describing the employment opportunities for civil drafters in the city and state in which you live.

P1-8 Research and write a report of approximately 250 words covering the American Society of Mechanical Engineers (ASME) standards accredited by the American National Standards Institute (ANSI). Prepare a PowerPoint presentation of your research and present the slide show to your class or office.

- P1-9** Research and write a report of approximately 250 words covering the International Standards Organization (ISO) drafting standards. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.
- P1-10** Research and write a report of approximately 250 words covering workplace ethics, especially as it applies to civil engineering design and drafting applications and CADD-related software. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.



CHAPTER

2

Computer-Aided Design and Drafting (CADD)

Learning Objectives

After completing this chapter, you will be able to:

- Discuss the applications of common CADD software programs.
- Define building information modeling (BIM).
- Identify U.S. National CAD Standard (NCS) recommendations.
- Explain and demonstrate basic CADD techniques.
- Identify standard sheet sizes and formats.
- Provide information about plotting and drawing scale.
- Explain file organization and management.
- Describe methods of productivity with CADD.
- Discuss the importance of ergonomics and positive work habits.

Key Terms

Computer-aided design and drafting (CADD)
Two-dimensional (2-D)
Three-dimensional (3-D)
Building information modeling (BIM)
Machine control
Virtual
Verticals
Attributes
Girder
Quantity take off (QTO)
Material take off (MTO)
Line work
Line conventions
Line weight
Line thickness
Layer
Text
Font
General notes
Field
Specific notes
Local notes
Delta note
Key note
General discipline notes
General sheet notes
Specifications
Specification

(continued)

Key Terms (*continued*)

MasterFormat	Plot device	Project files
Dimensions	Scale	Model file
Table	Model space	Sheet file
Schedule	Paper space	Drawing content
Symbol	Layout	Drawing template
Symbol library	Scale factor	Template
Soft copy	Exporting	Ergonomics
Hard copy	Library files	

Computer-aided design and drafting (CADD) is the process of using a computer with CADD software to produce drawings and models according to specific industry and company standards. The terms computer-aided design (CAD) and computer-aided drafting (CAD) refer to specific aspects of the CADD process. A computer loaded with CADD software is the primary tool used for creating drawings and calculating engineering data. This chapter is an introduction to CADD and explains a variety of basic CADD techniques, standards, and practices.

Civil CADD Software Products

Many CADD software manufacturers exist, and numerous products are available to meet industry needs. Software is available for **two-dimensional (2-D)** and/or **three-dimensional (3-D)** design and drafting. 2-D refers to a view displaying only width and height, width and length, or height and length. 3-D refers to a view displaying width, height, and depth. Some CADD software is general-purpose and can apply to any discipline. For example, Autodesk Inc. produces AutoCAD for 2-D and 3-D design and drafting. Other products focus on a specific CADD technology, industry, or discipline, such as drawings or models for civil engineering projects. For example, Bentley Systems, Inc. offers OpenRoads for 3-D road network design and analysis. Some CADD programs support expanded third-party or add-on utilities intended to increase system usefulness for specific applications such as water and sewer piping design and analysis.

Some companies offer specific applications or software packages to help manage all aspects of a project, known as **building information modeling (BIM)**. BIM is a unified sequence of processes through which a project passes from initiation to operation. You will learn more about BIM and related technology throughout this textbook.

Note: The following is an alphabetical introduction to common civil CADD software products at the time this textbook was published. There are many other CADD software manufacturers and numerous other CADD software products. The following material and software content throughout this textbook are not intended to promote or endorse any software manufacturer or product.

Autodesk, Inc.

Autodesk offers a wide variety of software. AutoCAD is a general-purpose 2-D and 3-D CADD software and is the core Autodesk product. Autodesk provides variations of AutoCAD for unique markets such as AutoCAD LT for 2-D drafting and AutoCAD Civil 3D for civil engineering. Additional Autodesk civil CADD products focus on specific civil engineering subdisciplines. Autodesk also offers BIM solutions including the Autodesk Building Design Suite. For more information about Autodesk, go to www.autodesk.com.

Bentley Systems, Inc.

Bentley Systems focuses on software for engineering and construction infrastructure design, documentation, and operation. MicroStation is a general-purpose 2-D and 3-D CADD software and is the primary Bentley Systems product. MicroStation also acts as a platform for other Bentley Systems software. For example, Power GEOPAK includes tools for civil engineering and transportation project design. MicroStation PowerDraft is a version of MicroStation mainly for 2-D drafting. Bentley Systems manufactures several other CADD products for specific civil engineering subdisciplines. Bentley Systems also offers BIM solutions designed to support each phase of the project life cycle. For more information about Bentley Systems, go to www.bentley.com.

Carlson Software

Carlson Software provides a wide range of software solutions for the survey, civil engineering, construction, and mining industries. All Carlson Software products can use AutoCAD as the base drafting software, or can run on Carlson Software's IntelliCAD. Some applications also run on MicroStation or other systems. There are many different Carlson Software products to address specific civil CADD requirements. For example, Carlson Civil provides advanced tools for roadway design, lot layout, and site grading. Another example, Carlson Grade software uses a digital terrain model (DTM) to guide heavy earthmoving equipment on a construction site in a process known as **machine control**. For more information about Carlson Software, go to www.carlsonsw.com.

Graphisoft

GRAPHISOFT focuses on software for the architecture, engineering, and construction (AEC) industry. ARCHICAD is a 3-D building design program with 2-D drafting and documentation capabilities and is the main GRAPHISOFT product. GRAPHISOFT also offers BIM solutions including BIMcloud, BIMx, and OPEN BIM. For more information about GRAPHISOFT, go to www.graphisoft.com.

Parametric Technology Corporation (PTC)

Parametric Technology Corporation (PTC) offers several software products generally focused on CADD in the manufacturing industry. However, PTC is also the manufacturer of PTC Mathcad. Mathcad is

a software that can be used by civil engineers to document and share complex engineering calculations. For more information about PTC, go to www.ptc.com.

Siemens Corporation

Siemens Corporation offers a wide variety of products and services. Siemens Product Lifecycle Management (PLM) for AEC and Infrastructure is an information and process management software for BIM. The product is designed to support project planning and engineering, civil engineering project execution, and information management. For more information about Siemens PLM solutions, go to www.plm.automation.siemens.com.

SketchUp

SketchUp is a free software for creating, sharing, and presenting 3-D models. SketchUp Pro is a premium version of SketchUp and includes all of the tools from the free version plus advanced settings for commercial use and interaction with other CADD programs. Common applications for SketchUp include sketching and modeling for visualization during the conceptual design phase of a project and creating presentation drawings that look hand sketched or photorealistic. SketchUp also links to Google Earth for sketching relative to a physical location, such as modeling a building on an actual lot. For more information about SketchUp, go to www.sketchup.com.

CADD Formats

Software specifies the CADD format. Some programs focus on 2-D drawing or 3-D modeling. Other software offers tools for working in multiple formats, or the ability to use drawing or model content created in a different format. For example, Figure 2–1 shows a 3-D model of a building construction project developed from survey data. The model is used to create the 2-D drawing of the site plan shown in Figure 2–2. Conversely, a 2-D drawing can be used to build a 3-D model. 2-D drawings are often required because they are the standard format in construction and serve as a legal document. For instance, the site plan shown in Figure 2–2 is one of many drawings required for a construction project. 2-D drawing is also effective for a project that is quick to design, does not require extensive revision, and does not require advanced visualization, simulation, and analysis.

3-D modeling is a better solution when a complex project can require extensive revision and when advanced visualization, simulation, and analysis are required. A 3-D virtual representation of a design can help overcome visualization problems and produce a realistic, testable project model. **Virtual** refers to something that appears to have the properties of a real or actual object or experience. The model shown in Figure 2–1, for example, allows for a variety of design applications from 3-D visualization and presentation to analyzing points, surfaces, and features to determine how each item affects the model.



Figure 2-1. A 3-D model of the site and structure for a proposed home construction project.
(Courtesy of Chief Architect Software)

CADD software provides commands and tools for creating and modifying all elements of a drawing or model for any design requirement. The process of preparing a drawing or model varies depending on the CADD software and preferred design and drafting techniques. Basic CADD software typically requires you to construct geometry such as lines, circles, arcs, and 3-D shapes, and add dimensions and text. Software typically includes varying levels of functionality that helps improve design and drafting efficiency and automate common tasks.

Industry-specific versions of software, sometimes referred to as **verticals**, provide tools for particular design requirements and intelligent modeling functions. For example, the software used to create the roadway intersection layout shown in Figure 2-3 incorporates intelligent roadway design features. In this example, two roadway centerlines are used to model an intersection. If the geometry defining either of the roads is modified, the intersection model can update automatically, reconstructing the necessary pavement, curbs, gutters, and sidewalks according to the new location of the intersecting centerlines.

Building Information Modeling (BIM)

Components of a project life cycle include all elements of design, construction, and operation. Traditionally, each component has functioned independently, with communication occurring only when the design was passed to the next group. Communication from one end of the process to the other was often limited. This approach frequently results in expensive and time-consuming revisions and engineering

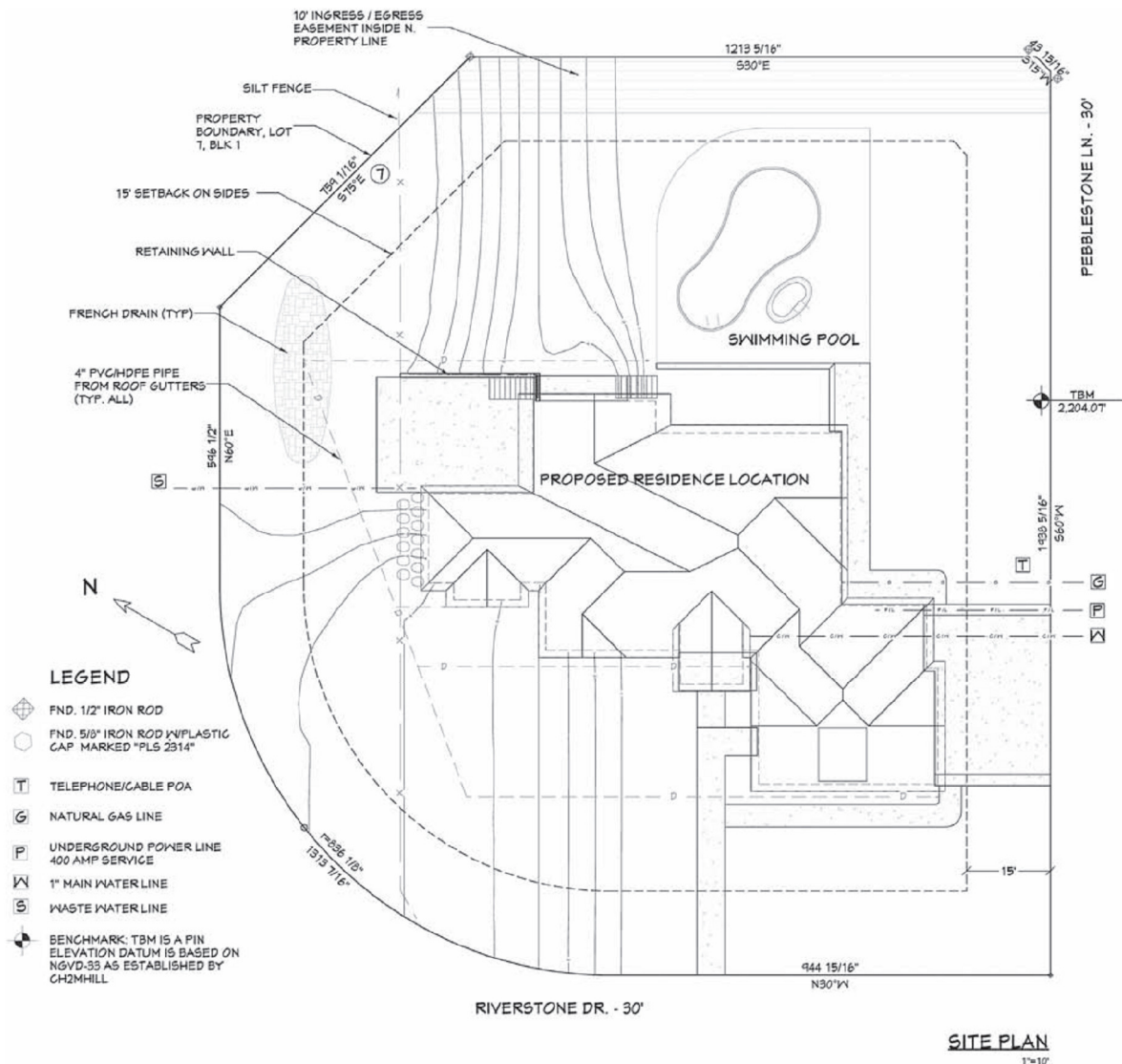
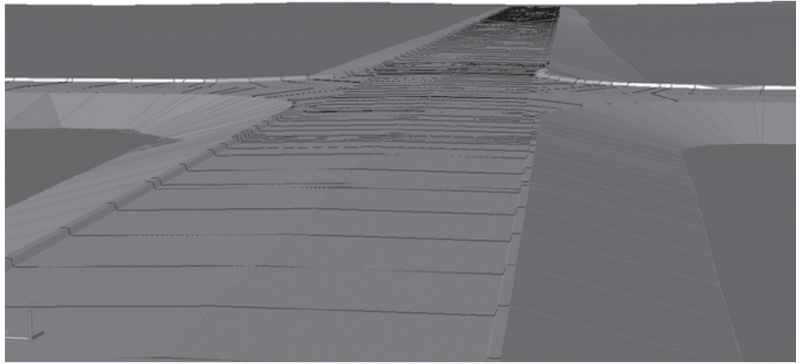


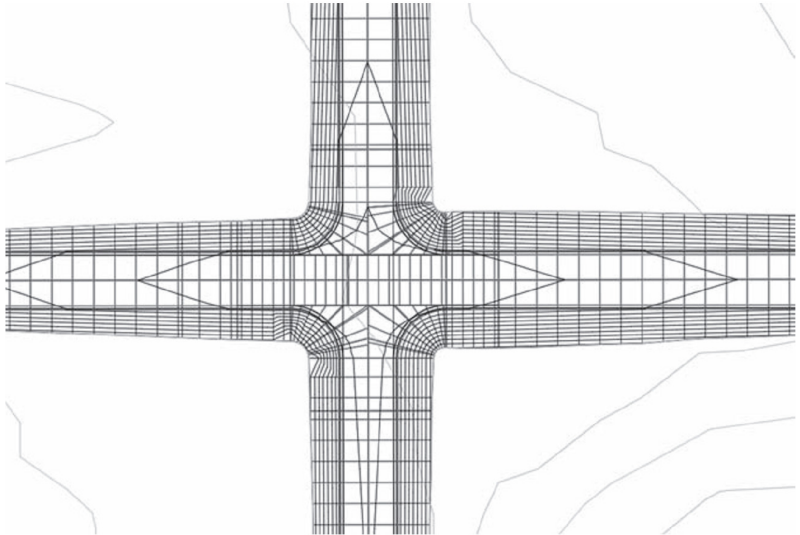
Figure 2-2. A 2-D drawing of a site plan created from the 3-D model shown in Figure 2-1.
(Courtesy of Chief Architect Software)

changes. Cost of construction, time to completion, and the demand for quality construction have driven a change from this linear process to an integrated approach that brings together a team of people from all aspects of project development. BIM is a process being used to change traditional practices, resulting in quality construction designed quickly, using all parties in the design process concurrently.

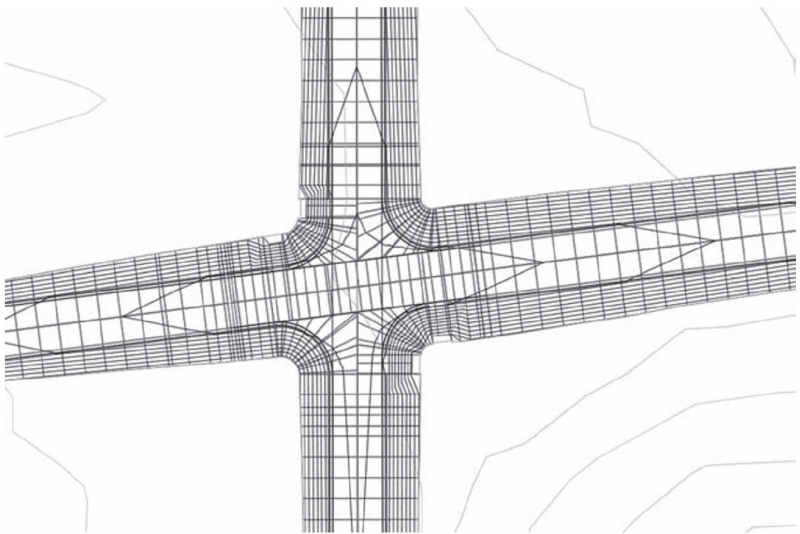
BIM includes tools for planning, designing, areas of project management, and facility operation (see Figure 2-4). Several software manufacturers offer products to support BIM. BIM includes a 3-D model that helps facilitate efficient and accurate communication between designers, clients, contractors, and tradespeople associated with a construction project. The roadway layout shown in Figure 2-3 is a fundamental element of BIM. In this example, all of the roadway



3-D Model



Original Design



Redesign

Figure 2-3. Using software with intelligent roadway design features to make dynamic changes to a roadway model.
(Courtesy of Eric Chappell and Autodesk, Inc.)

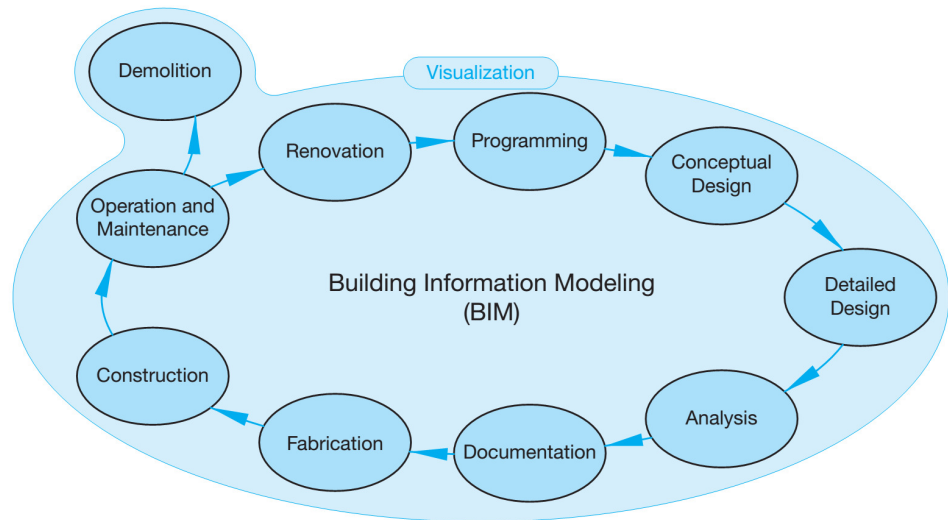


Figure 2-4. BIM is designed to help manage all aspects of a project.

features relate to each other dynamically and include attributes. **Attributes** are text-based data assigned to a specific object. The BIM process uses this model for everything associated with the planning, engineering, testing, construction, marketing, cost analysis, operations, and maintenance of the roadway.

Figure 2-5 shows a 3-D model of a bridge design. This model includes the individual structural components of the bridge that can be used throughout the BIM process. Notice how the software stores information about the model components such as the structural shape and dimensions of the highlighted girder. A **girder** is a horizontal structural



Figure 2-5. A 3-D model of bridge design captured from Autodesk InfraWorks 360 software. (Courtesy of Eric Chappell and Autodesk, Inc.)

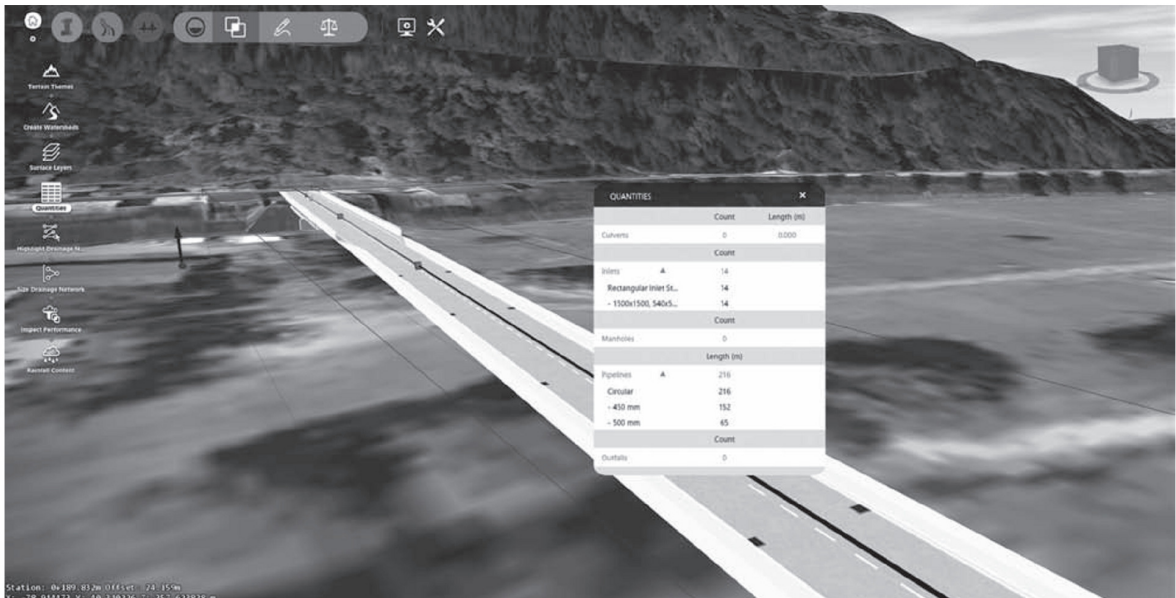


Figure 2–6. The quantity take off (QTO), or material take off (MTO), report extracted from a 3-D model of a road specifies the drainage system components and their associated quantities.
(Courtesy of Eric Chappell and Autodesk, Inc.)

member that spans between two or more supports. Planners and engineers use the model to work with clients and contractors to develop the preferred design. Engineers can optimize the design using model analysis, simulation, and visualization. A model like this can then be used to generate construction documentation such as 2-D drawings and the quantity take off (QTO) report for the roadway drainage system shown in Figure 2–6. **QTO**, or **material take off (MTO)**, refers to a list, or the process of generating a list, of materials and other information such as the quantities and weights of materials required for a construction project. A 3-D model can even be integrated into a system that uses global navigation satellite system (GNSS) technology to guide the earthmoving equipment used to build the road. You will learn more about GNSS later in this textbook. The BIM process continues after construction as those assigned to maintain the road reference the model. The model can be used again in the future if there is a need to expand or widen the road, or to remove the road.

BIM Standards

The National BIM Standard-United States (NBIMS-US) is a set of BIM standards created by the National Institute of Building Sciences (NIBS) buildingSMART alliance. The goal of the NIBS buildingSMART alliance is to establish, through the NBIMS-US project, the necessary standard and structure so that end-users throughout all facets of the industry can use BIM to efficiently access the information needed to create and operate optimized facilities. For more information about the NBIMS-US, go to www.nationalbimstandard.org or www.nibs.org.

Note: The U.S. National CAD Standard (NCS), explained in more detail in the next section of this chapter, includes a BIM implementation component. The BIM implementation section covers the application of standards for BIM use by defining principles specific to BIM.

The U.S. National CAD Standard (NCS)

The U.S. National CAD Standard (NCS) is a set of standards intended to simplify and increase the efficiency and accuracy of CADD data exchange among owners, architects, designers, and construction teams. The NCS was developed by several organizations, and it focuses on AEC projects. The American Institute of Architects (AIA), Construction Specifications Institute (CSI), and the National Institute of Building Sciences (NIBS) contribute to the NCS. Applying the NCS can result in reduced costs for developing and maintaining office standards and greater efficiency in the transfer of building design information from design to construction. The NCS includes four major components:

- AIA CAD Layer Guidelines
- Uniform Drawing System (UDS)
- BIM Implementation
- Plotting Guidelines

The NCS is a vast set of standards. Many of the specific standards presented in the NCS focus on architectural CADD for building construction projects. However, the NCS includes elements that apply directly or can be adapted to CADD for civil engineering projects. The NCS is not intended to be applied with any specific CADD software program, but AutoCAD and MicroStation were selected as the primary applications because of their popularity. You will explore NCS applications throughout this textbook. For more information about the NCS, go to www.nationalcadstandard.org or www.nibs.org.

Basic CADD Techniques

Civil drafting is a graphic language made up of lines, shapes, symbols, and text. When these items are effectively put together, they produce drawings that are used in the construction of civil engineering projects. There are many techniques and standards associated with the creation of quality engineering drawings, such as line work and text methods and standards. It is your responsibility to use and interpret design and drafting systems and conventions to produce the best possible drawings.

CADD software provides commands and tools for creating and modifying all elements of a drawing or model for any design requirement. Design and drafting concepts and theories are the same regardless of the specific CADD software and technique used to produce the drawing. This chapter provides an introduction to basic CADD techniques. You will learn drafting practices for specific applications throughout this textbook.

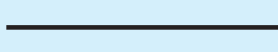
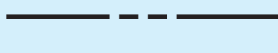
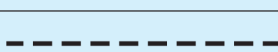
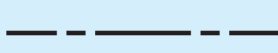
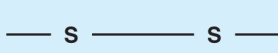
Appearance	Purpose	Characteristics	AutoCAD Linetype
	City, county, or state boundary	0.014–0.028"/0.35–0.70 mm thickness, solid.	Continuous
	Subdivision boundary and property line	0.014–0.028"/0.35–0.70 mm thickness, two short dashes alternating with one long dash.	PHANTOM
	Property line and lot line	0.014–0.020"/0.35–0.50 mm thickness, solid.	Continuous
	Easement line	0.010–0.014"/0.25–0.35 mm thickness, short dashes.	DASHED or HIDDEN
	Center line	0.010–0.014"/0.25–0.35 mm thickness, one short dash alternating with one long dash.	CENTER
	Proposed water	0.014–0.028"/0.35–0.70 mm thickness, longer dashes.	DASHED, HIDDEN, or DASHEDX2
	Proposed sewer	0.014–0.028"/0.35–0.70 mm thickness, one short dash alternating with one long dash.	CENTER
	Existing water	0.010–0.014"/0.25–0.35 mm thickness, Ws alternating with one long dash.	Custom
	Existing sewer	0.010–0.014"/0.25–0.35 mm thickness, Ss alternating with one long dash.	Custom

Figure 2-7. Lines commonly used in civil drafting.

Line Work

Line work refers to the placement and correct use of lines, shapes, and symbols on a drawing. Line work typically represents the majority of information on an engineering drawing. Civil drafting line work is done using a number of techniques, depending on the purpose of the drawing and specified line conventions. **Line conventions** are the standards related to line weight, type, color, and purpose. **Line weight**, or **line thickness**, is the assigned width of lines for display and plotting. Figure 2-7 shows a few of the line types used in civil drafting.

There are a variety of line types found on drawings. Each type of line conveys a meaning by the way it is represented and its placement on the drawing. Assigning line weight and type to different objects provides a way to classify the content of the drawing to improve readability. Features drawn with thicker lines stand out from items drawn with thinner lines. ASME standards recommend two line thicknesses to establish contrasting lines: 0.02" (0.6 mm) thick lines and 0.01" (0.3 mm) thin lines. Figure 2-8 identifies the NCS line weight recommendations. When following NCS line weight recommendations, it is common practice to select an assortment of line thicknesses that correlate best to specific applications. The thin, medium, wide, and extra wide thicknesses specified in the NCS are adequate for most drawings.

Assigning color to lines helps distinguish objects on-screen, and is necessary when plotting a drawing in color. Line colors should emphasize important features and symbols, aid in clarity and visualization,

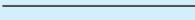
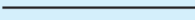
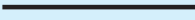
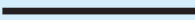
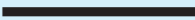
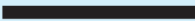
Line Thickness	Appearance	Inches	Millimeters	Application
Extra fine		0.005	0.13	Fine detail.
		0.007	0.18	Material patterns, section lines, hatch patterns.
Thin		0.010	0.25	Text: 3/32"–3/8" (2.5–10 mm). Dimensioning features, phantom lines, hidden lines, centerlines, long break lines, schedule grid lines, background objects.
Medium		0.014	0.35	Text: 5/32"–3/8" (4–10 mm). Object lines, property lines, text for notes and in schedules, terminator marks, schedule grid accent lines.
Wide		0.020	0.50	Text: 7/32"–3/8" (6–10 mm). Major object lines at elevation edges, cutting-plane lines, short break lines, title text, border lines.
Extra wide		0.028	0.70	Text: 1/2"–1" (13–25 mm). Minor title underlines, schedule outlines, large titles, special emphasis object lines, elevation and section grade lines, sheet borders, schedule borders.
2X wide		0.040	1.00	Major title underlines, separating portions of a drawing.
3X wide		0.055	1.40	Border lines, cover sheet lines, artwork.
4X wide		0.079	2.00	Border lines, cover sheet lines.

Figure 2–8. Line weights recommended by the NCS.

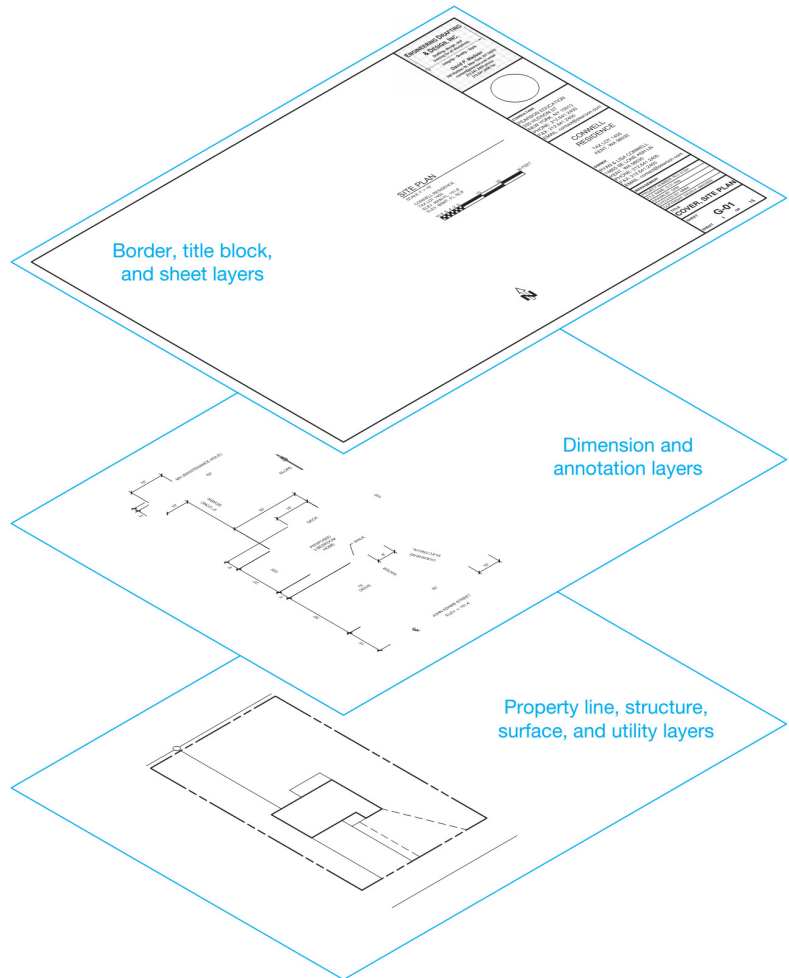
and not cause eyestrain. The NCS Uniform Drawing System, Symbols module provides specific recommendations regarding the use of color on plotted drawings, especially as it relates to text and symbols.

Note: The NCS Uniform Drawing System, Drafting Conventions module addresses standard practices used on drawings, such as drawing orientation, layout, symbols, material indications, line types, dimensions, drawing scale, diagrams, notation, and cross-referencing.

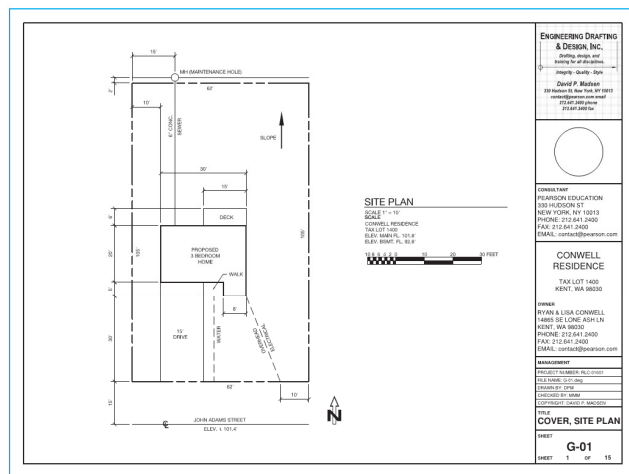
Layers

A **layer** is a logical grouping of data. Layers allow you to organize properties such as line weight, line type, and color, and assign the properties to objects. You can consider layers to be a series of drawing overlays. Civil engineering drawings may require hundreds of layers, each used to produce a specific item. Examples of civil drafting layers are border, title block, property lines, contours, elevations, structures, roads, parking areas, utilities, dimensions, and notes. Figure 2–9 shows how layers are used when drawing a site plan. The following is a list of ways layers can increase productivity and add value to a drawing:

- Assign each layer a different line weight, line type, and color to correspond to line conventions and to help improve clarity.
- Make changes to layer properties to update all objects drawn on the layer.



(a)



(b)

Figure 2-9. (a) The basic concept of how layers organize and manage elements of a site plan. Typically, each group of items is drawn on its own layer. (b) Display all layers to show the complete drawing.

- Hide selected layers to decrease the amount of information displayed on-screen or to speed up screen regeneration.
- Plot each layer in a different line weight, line type, and color, or set a layer not to plot.
- Use separate layers to group specific information. For example, draw a plat using plat layers, and a grading plan using grading layers.

The AIA CAD Layer Guidelines, a component of the NCS, specifies a layer naming system for AEC drawings. The system uses a highly detailed layer naming process that assigns each layer a discipline designator and major group, and if necessary, one or two minor groups and a status field. The AIA system allows complete identification of drawing content. In this format, layer names are based on abbreviations that are easy to recognize. Figure 2–10 provides the examples of layer names. Figure 2–11 lists some of the many common civil drafting layers.

Note: A layer management system and record keeping are very important. Record layers in a procedures manual or drawing log, with information about the properties assigned to each layer and how each layer is used.

Text

Text is the lettering on a CADD drawing. Consistent text type, format, height, and spacing are critical to legibility and drawing clarity. CADD provides commands and settings to create uniform, easy-to-read text according to drafting standards. A variety of text styles and fonts are available, and text commands and options provide great control over text composition. **Font** is the face design of a letter or number. The style of text used on civil drawings varies depending on

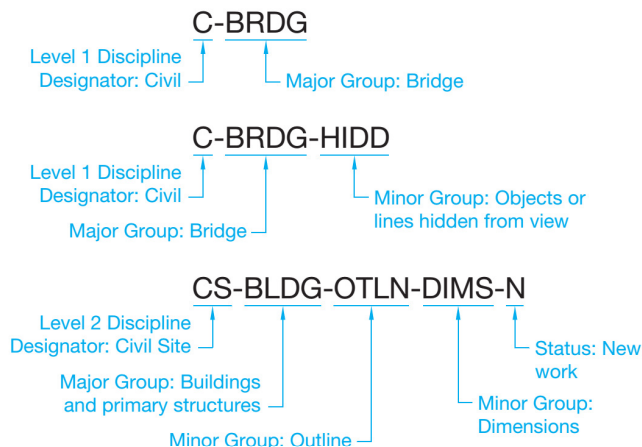


Figure 2–10. Examples of AIA CAD Layer Guidelines layer names.

Layer Name	Discipline Designator	Description
C-ANNO	Civil	Annotation
C-ANNO-NOTE	Civil	Notes
C-BLDG-DECK	Civil	Buildings and primary structures: deck
C-COMM-OVHD	Civil	Communications: overhead
CD-DRIV	Civil Demolition	Driveways
C-ESMT	Civil	Easements
C-FENC	Civil	Fences
CG-TOPO	Civil Grading	Topographic features
C-NGAS-UGND	Civil	Natural gas systems: underground
C-POWER	Civil	Power
C-PRKG	Civil	Parking lots
C-PROP-LINE	Civil	Property: lines
C-PROP-SBCK	Civil	Property: setback lines
C-RIVR	Civil	River
C-ROAD-CNTR	Civil	Roadways: center
C-ROAD-DIMS	Civil	Roadways: dimensions
CS-AFLD	Civil Site	Airfields
C-SSWR	Civil	Sanitary sewer
C-STRM	Civil	Storm sewer
L-IRRG	Landscape	Irrigation
L-PLANT	Landscape	Plant and landscape material
V-BNDY	Survey/Mapping	Political boundaries
V-CTRL	Survey/Mapping	Control points
V-NODE-CURB	Survey/Mapping	Node: curb

Figure 2-11. Some of the layers listed in the AIA CAD Layer Guidelines common to civil drafting.

the established standards and project requirements, but plain vertical text is most common. Refer to Figure 2-12 as you read the following information about text fonts and formats.

The text style described by ASME standards can be achieved using a font such as Arial, Romans, or Century Gothic. The NCS recommends a sans serif font, which can be achieved with a font such as the Arial, RomanS, or SansSerif. Some architectural and civil engineering companies prefer a more traditional architectural hand-lettering appearance for text, which can be achieved using a font such as Stylus BT or CountryBlueprint.

Vertical text is most common on engineering drawings. However, inclined text is an approved national standard and is used by some civil engineering companies. Inclined text is also used for specific drawing requirements, such as water-feature labels on maps. The recommended slant for inclined text is 68° from horizontal, although some drafters find 75° more appropriate. Uppercase text is standard. However, some civil engineering companies use lowercase letters for some applications such as titles.

A drawing displays specific text heights for different purposes. ASME standards generally specify minimum letter heights of 0.10" (2.5

TRACT "F" OPEN SPACE

Vertical uppercase, Arial font

APPROXIMATELY 8.327 ACRES.

Vertical uppercase, RomanS font

SHEET 3 OF 6

Vertical uppercase, Century Gothic font

WATER LINE PIPE SHALL
HAVE A MINIMUM OF 36" OF
COVER TO FINISH GRADE.

Vertical uppercase, SansSerif font

TRACT A IS A PRIVATE ACCESS TRACT
AND SHALL BE OWNED AND MAINTAINED
BY HOMEOWNERS ASSOCIATION.

Vertical uppercase, Stylus BT font

WALL FOUNDATION AND EXCAVATION VARIES.

Vertical uppercase, CountryBlueprint font

NORTH LIGHTNING CREEK NO. 1

Inclined uppercase, Times New Roman font, bold

Stormwater Water Quality Pond for all Parking

Vertical lowercase, Arial font

Missouri River

Inclined lowercase, SansSerif font

Figure 2-12. Examples of common text typefaces and formats.

mm) for sheet block headings, 0.12" (3 mm) for most text, and 0.24" (6 mm) for titles, depending on sheet size. The NCS and many civil engineering companies and agencies depart slightly from the ASME standard. The NCS specifies a minimum text height of 3/32" (2.4 mm). In general, dimensions and notes should be 0.12" or 0.125" (3 mm) high. Text any smaller than 0.12" is difficult to read. Titles, headings, and certain other notes are often 0.24" or 0.25" (6 mm) high to easily distinguish them from other text. Text should be uniform and consistent throughout a drawing. Most drawings need only two or three different text heights. All text of the same group—for example, all dimensions and notes—should have the same text height when possible.

Notes and Specifications

Notes on a drawing provide written information such as comments, explanations, or specifications. **General notes** are notes that apply to an entire drawing (see Figure 2-13). General notes are typically

NOTES:

1. CONTRACTOR TO VERIFY LOCATION OF ALL EXISTING UTILITIES.
2. ALL FINISH GRADES SHALL BE SMOOTH AND UNIFORM.
3. PROVIDE POSITIVE DRAINAGE AWAY FROM BUILDING.
4. FINAL GRADE TO CONVEY SURFACE DRAINAGE TOWARD FRENCH DRAIN.
5. AREAS TO BE FILLED SHALL BE CLEARED; GRUBBED TO REMOVE TREES, VEGETATION, ROOTS AND OTHER OBJECTIONABLE MATERIAL; AND STRIPPED OF TOPSOIL.

Figure 2-13. General notes apply to an entire drawing.

placed in the lower-left or lower-right corner of the drawing, but can be placed anywhere in the field of the drawing, depending on specified standards. The **field** is any open area that surrounds the main views displayed on the drawing. General notes should be placed 1/2" (13 mm) from the drawing border.

Specific notes, or **local notes**, are notes that relate to or identify specific, isolated features or instructions within the drawing. Specific notes are often connected to the feature using a leader line (see Figure 2-14). Specific notes can also be placed directly next to the feature without using a leader. Specific notes that are too complex or take up too much space can be placed with general notes and keyed to the drawing with an identification, such as SEE NOTE 3 or NOTE #3. A number or letter with a symbol can also be used to key a note to a feature in the drawing, such as the numbers framed in hexagons shown in Figure 2-15. This is referred to as a **delta note** or **key note**. Circles, triangles, squares, rectangles, and ellipses can also be used as the key note symbol.

The NCS Uniform Drawing System, Notations module provides guidelines for note classification, format, components, and location.

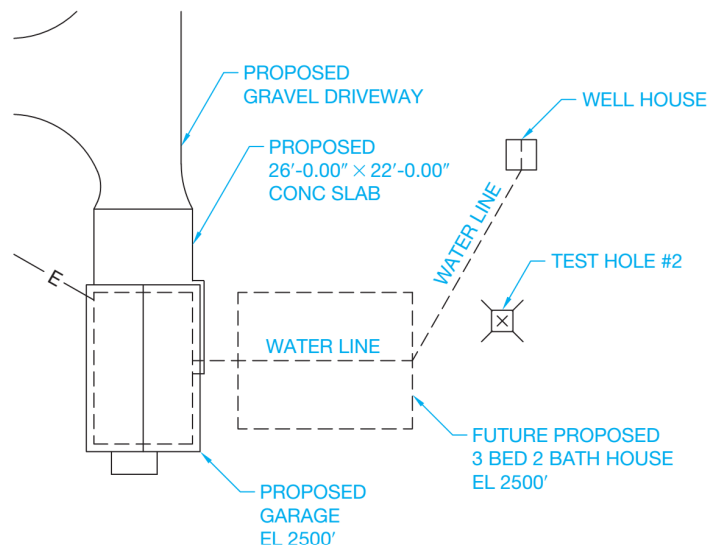


Figure 2-14. A portion of a site plan with several specific notes.

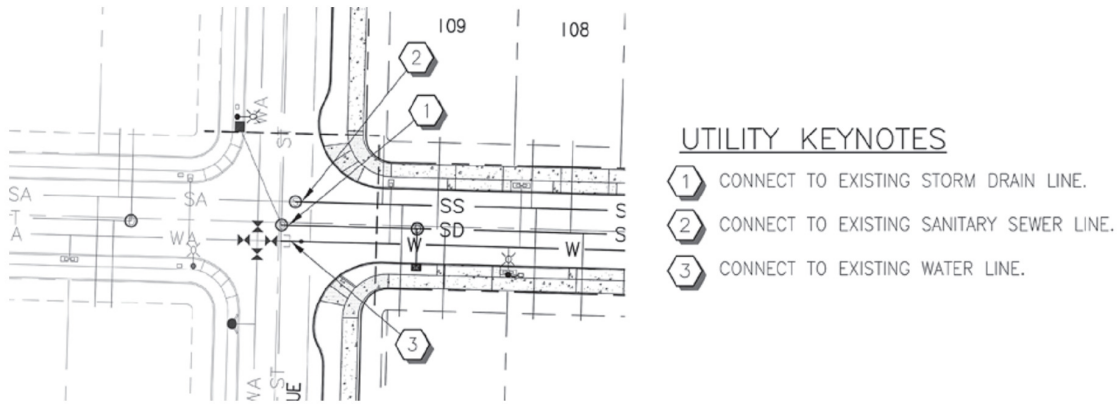


Figure 2-15. A portion of a composite utility plan with key notes used to link specific notes to features in the drawing.
(Courtesy of Otak, Inc.)

The module includes the use of notes, terminology, and linking drawing notes to specifications. The NCS recommends general discipline notes and general sheet notes in addition to general notes and key notes. **General discipline notes** are notes that reflect information about specific disciplines, such as sewer, water, or other utilities. **General sheet notes** are notes that provide information about the sheet or sheets in a set of drawings.

Specifications are separate notes that identify the quality, quantity, type of material used, workmanship, and other detailed information about a project. A **specification** is an exact statement describing the characteristics of a particular aspect of a project. Specifications are generally prepared in a format that is different from standard drawing sheets. Specifications can be printed in a format that categorizes each phase of construction and indicates the exact methods and materials to be used. Specifications often follow company guidelines, although the MasterFormat published by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC) provides a common format. The **MasterFormat** is a list of numbers and titles that is created for the organization of information into a standard sequence that relates to construction requirements, products, and activities. For more information about MasterFormat, go to www.csinet.org or www.csc-dcc.ca.

Dimensions

Dimensions describe the size, shape, or location of features on an object or structure. A dimension typically includes numerical values, lines, symbols, and notes (see Figure 2-16). Civil drawings are generally dimensioned in feet (') and inches ("), such as 25'-6", or in decimal feet, such as 25.5'. Metric drawings are typically dimensioned in millimeters (mm) or meters (m).

Numbers in dimensions and notes are often the same height as the standard text. CADD provides several methods for stacking text in fractions. When dimensions contain fractions, the fraction bar often

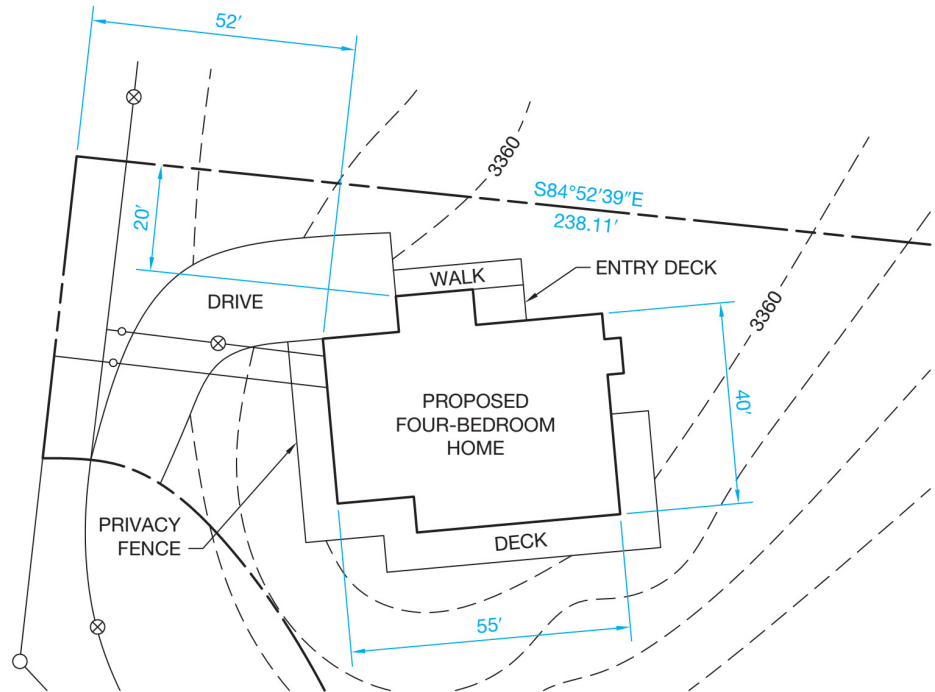


Figure 2-16. A portion of a site plan with several dimensions.

appears horizontally between the numerator and denominator. However, many notes have fractions displayed with a diagonal fraction bar (/). In this case, use a dash or space between the whole number and the fraction.

Note: The NCS Uniform Drawing System, Terms and Abbreviations module provides standard terms and abbreviations used in construction documents and specifications. This module provides consistent spelling and terminology, standardizes abbreviations, and notes common usage.

Tables

A **table** is an arrangement of rows and columns that organize data to make it easier to read. Tables are common elements of engineering drawings. Examples of tables are bills of materials (BOMs), charts, legends, MTO sheets, schedules, and sheet blocks. A **schedule** is a grouping of related items with corresponding distinguishing features, headings, and a minimum of three columns of related information. Figure 2-17 shows two examples of tables taken from civil engineering drawings. The NCS Uniform Drawing System, Schedules module provides standard formats for schedules used in construction documents, and has an organizational system for identifying and filing schedules.

INDEX OF SHEETS	
SHEET NO.	DESCRIPTION
1	CONCRETE REMOVAL
2	PLAN
3	PROFILES
4	CONCRETE PLACEMENT SCHEDULE
5	CONCRETE DETAILS
6	WALKWAY, HANDRAIL, AND BRIDGE DETAILS
7	GATE DETAILS
8	GENERAL REINFORCEMENT DETAILS

(a)

TOTAL ESTIMATED QUANTITIES			
ITEM NO.	ITEM	UNIT	ESTIMATED QUANTITY
1	MOBILIZATION	LS	1
2	REMOVAL OF STRUCTURES	LS	1
3	STRUCTURE	LS	1
4	RIP RAP	CY	280
5	FILTER AGGREGATE	CY	60
6	SILT FENCE	LF	100

(b)

Figure 2-17. (a) A table placed on the cover sheet in a set of drawings to identify the sheets in the set. (b) A table listing total estimated quantities for a civil engineering project.

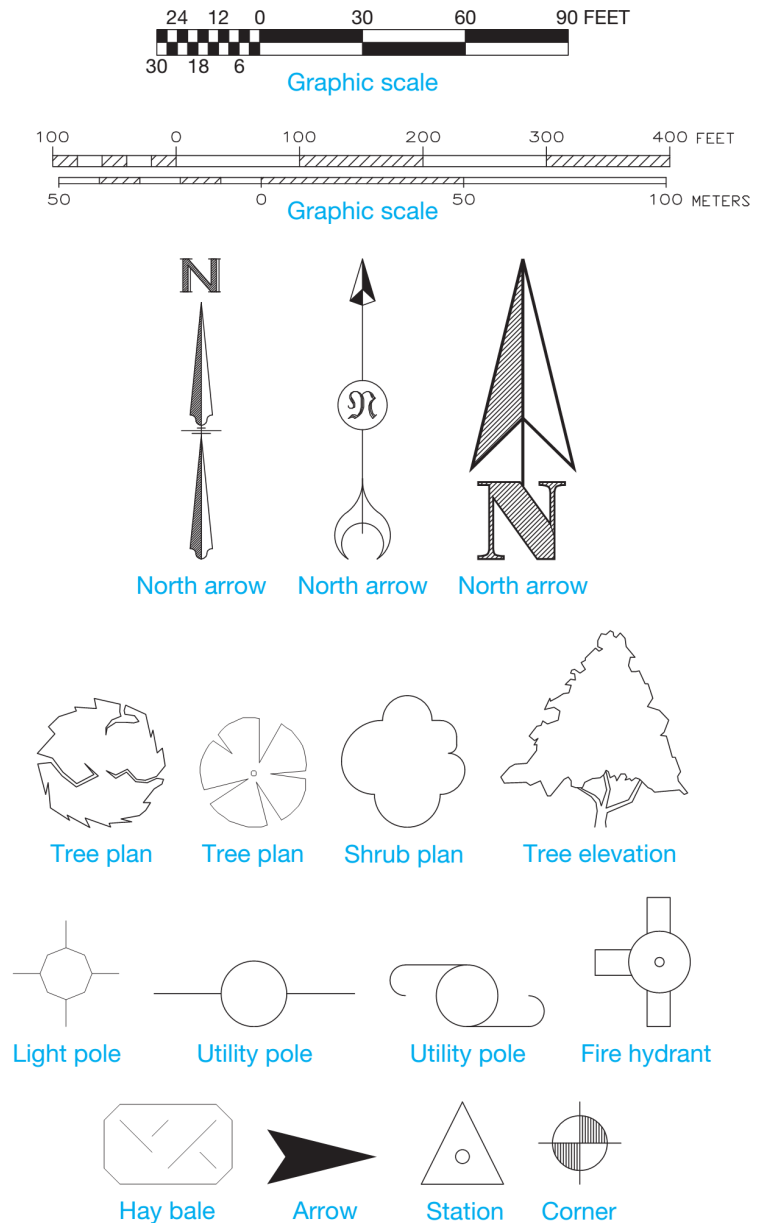
Symbols

A **symbol** is a graphic representation of a feature or an object. One of the great benefits of CADD is the ability to draw a symbol, save it, and reuse the symbol as needed. Most engineering companies and agencies have an extensive library of saved symbols and drawings. A **symbol library** is a directory of symbols that can be accessed for using on a drawing. Symbol libraries can contain hundreds or thousands of symbols. A project may use many standard symbols and details, some requiring minor changes in dimensions, materials, and construction methods. It is important for you to be aware of the kinds of symbols and details that are archived in drawing and symbol libraries. Figure 2-18 shows several civil drafting symbols. Chapter 4 explains symbols in more detail.

The NCS Uniform Drawing System, Symbols module addresses commonly used standard symbols, classifications, graphic representation, and organization in creating, understanding, and fulfilling the intention of construction documents. The standard provides a complete range of recommended symbols for all disciplines. The following is a list of the classification of symbols by type:

- Reference symbols
- Line symbols
- Identity symbols

Figure 2-18. Common civil drafting symbols.



- Object symbols
- Material symbols
- Text symbols

Sheet Size and Format

Most engineering drawings follow specific standards for sheet size and format. Civil drafting sheet size and format is based on required standards and company practices. ASME standard sheet sizes are common across all disciplines, and the ASME sheet format recommendations

ANSI Inch Sheet Sizes in Inches		
Size Designation	Vertical	Horizontal
A	8 1/2	11 (horizontal format)
	11	8 1/2 (vertical format)
B	11	17
C	17	22
D	22	34
E	34	44
F	28	40
Sizes G, H, J, and K are roll sizes.		
ISO Metric Sheet Sizes in Millimeters		
Size Designation	Vertical	Horizontal
A4	210	297
A3	297	420
A2	420	594
A1	594	841
A0	841	1189
Architectural Sheet Sizes in Inches		
Size Designation	Vertical	Horizontal
A	9	12 (horizontal format)
	12	9 (vertical format)
B	12	18
C	18	24
D	24	36
E	36	48

Figure 2-19. Standard drafting sheet sizes.

can be adapted to civil drafting. Civil engineering drawings are also commonly prepared on architectural sheet sizes. Follow sheet size and format standards to improve readability, handling, filing, and drawing reproduction. Sheet size and format standards also help to ensure that all necessary information appears on the sheet.

Sheet Sizes

ASME standards recommend ANSI standard sheet sizes for U.S. customary (inch) drawings and ISO standard sheet sizes for metric drawings. The NCS Uniform Drawing System, Sheet Organization module recommends ANSI, ISO, and architectural standard sheet sizes. Figure 2-19 lists ANSI, ISO, and architectural standard sheet sizes. Longer lengths are referred to as elongated and extra-elongated drawing sheet sizes.

When selecting a sheet size, consider the size of objects drawn; the drawing scale; the amount of additional content on the sheet such as a border, title block, and notes; and drafting standards. In general, choose a sheet size that is large enough to show all elements of the drawing using an appropriate scale and without crowding. Often specific project

requirements control sheet size. For example, a civil engineering firm might use ANSI D or architectural D size sheets for most projects, but might be required to submit certain drawings on ANSI A or ANSI B size sheets. U.S. government agencies typically require ANSI sheet sizes.

Sheet Format

A sheet usually includes elements such as a border and title block. A standard sheet format helps to ensure that all necessary information appears in the sheet blocks and on the surrounding sheet next to the border so that the drawing is easy to read and file. ASME standards dictate the exact size, location, appearance, and content of items on a sheet. Figure 2–20 shows standard ASME sheet sizes and layout. Companies often modify or add content to a sheet not directly specified by accepted standards. Common examples include blocks for additional CADD file information, copyright and propriety statements, and engineering stamps.

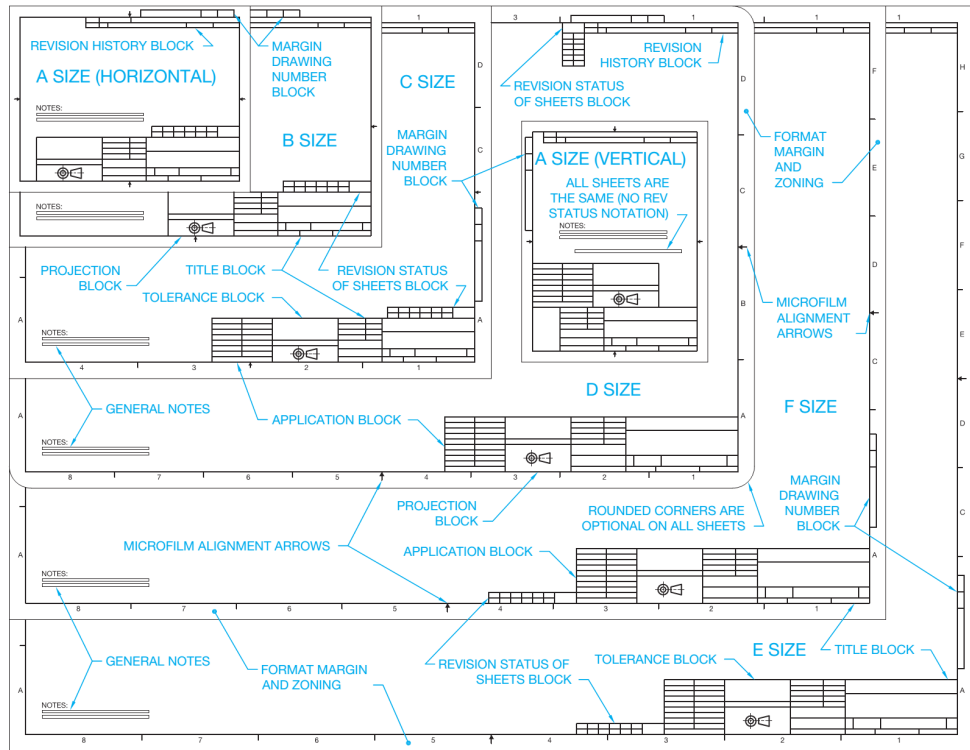
The NCS Uniform Drawing System, Sheet Organization module also establishes standards for sheet sizes and format. A graphic layout divides the sheet into the drawing, title block, and note areas shown in Figure 2–21. There is also a grid system for organizing drawing information on a sheet. The title block format includes content placement locations, but allows flexibility for company design. The NCS recommends that title blocks be placed vertically along the right side of the sheet and contain the following compartments:

- Designer identification block—The logo or name of the agency or company.
- Issue block—Revision area or addenda.
- Management block—Information about the designer, checker, and drafter.
- Project identification block—Project name and location.
- Sheet identification block—The sheet identifier.

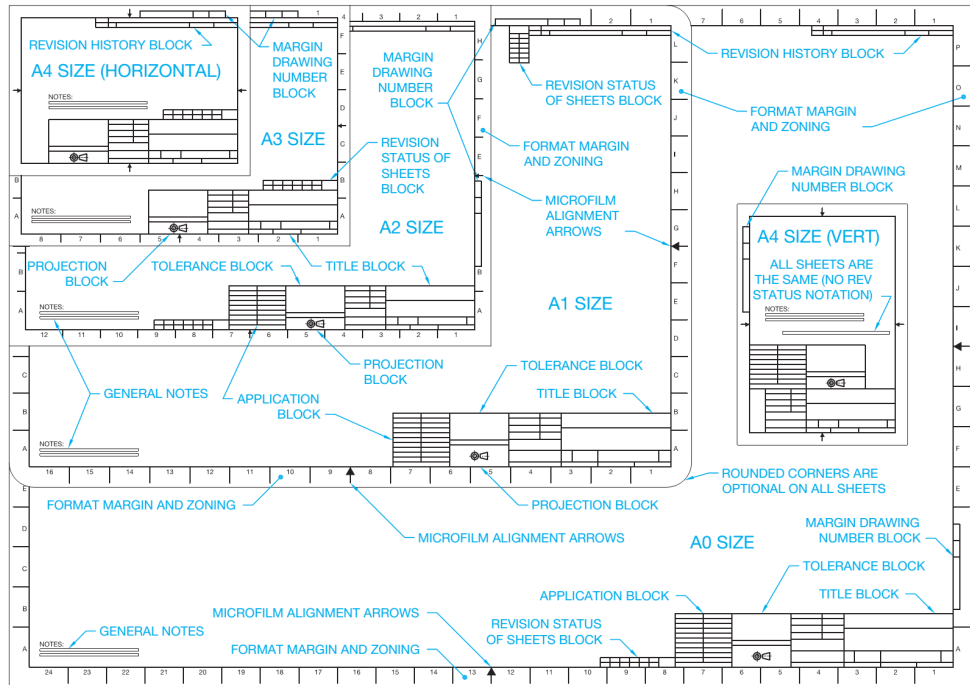
Sheet Identification Standards

The NCS Uniform Drawing System, Drawing Set Organization module covers drawing units, file naming, and sheet identification. The sheet identification system uses a detailed sheet naming process that assigns each sheet a discipline designator, sheet type designator, sheet sequence number, and user-defined characters. The module also establishes the order of presentation of disciplines within a drawing set. The sheet identifier is located in the title block and in any reference to the sheet on a drawing. Figure 2–22 provides some examples of sheet names.

Note: The NCS Uniform Drawing System, Code Conventions module identifies types of general regulatory information that should appear on drawings, locates code-related information in a set of drawings, and provides standard graphic conventions. This module can be a tool to speed up code review by designers and plan review authorities.

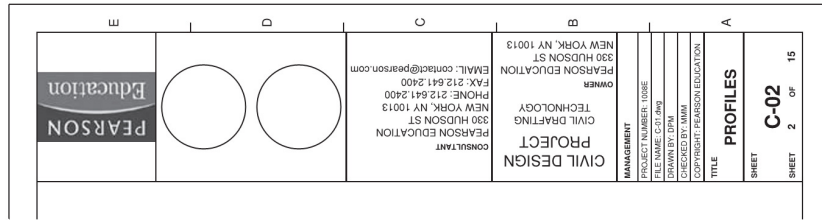


(a)

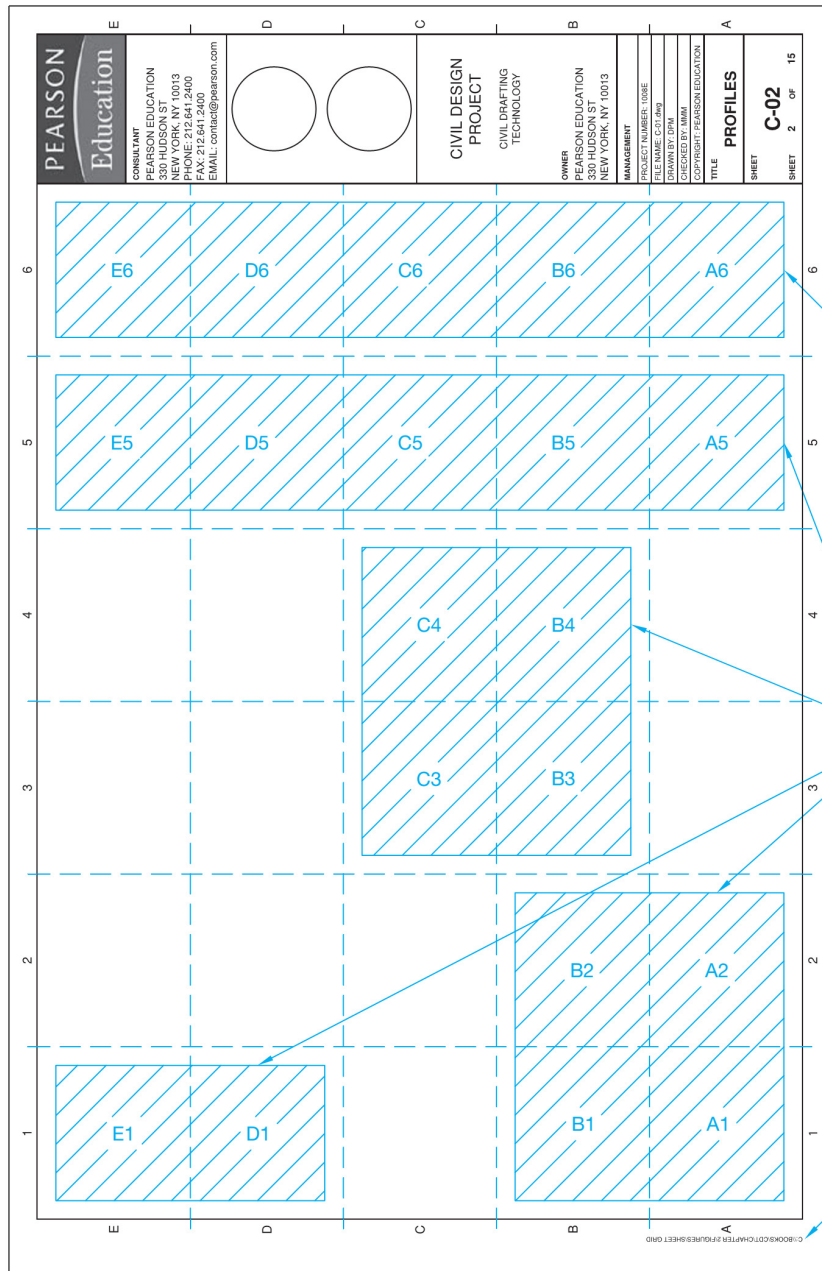


(b)

Figure 2-20. (a) ASME standard decimal inch drawing sheet sizes and layout. (b) ASME standard metric drawing sheet sizes and layout.



Vertical title block format



Horizontal title block format

Note block

Drawing blocks

Production data

Figure 2-21. The NCS drawing area coordinate system. The title block can be drawn in a horizontal or vertical text format. Notice how the sheet identification block, sheet title block, and management block are always oriented horizontally.

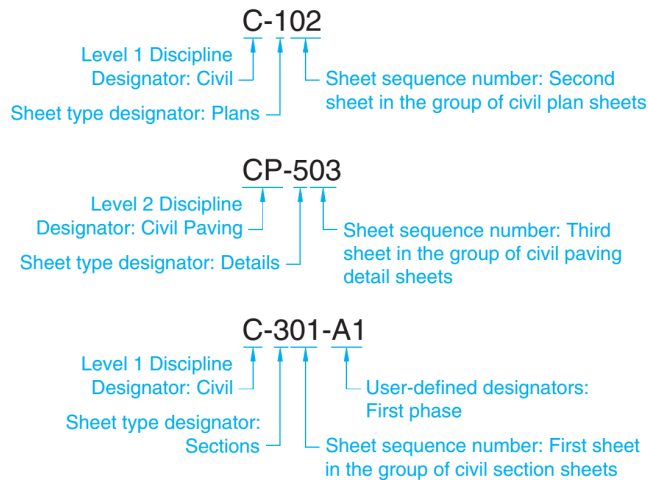


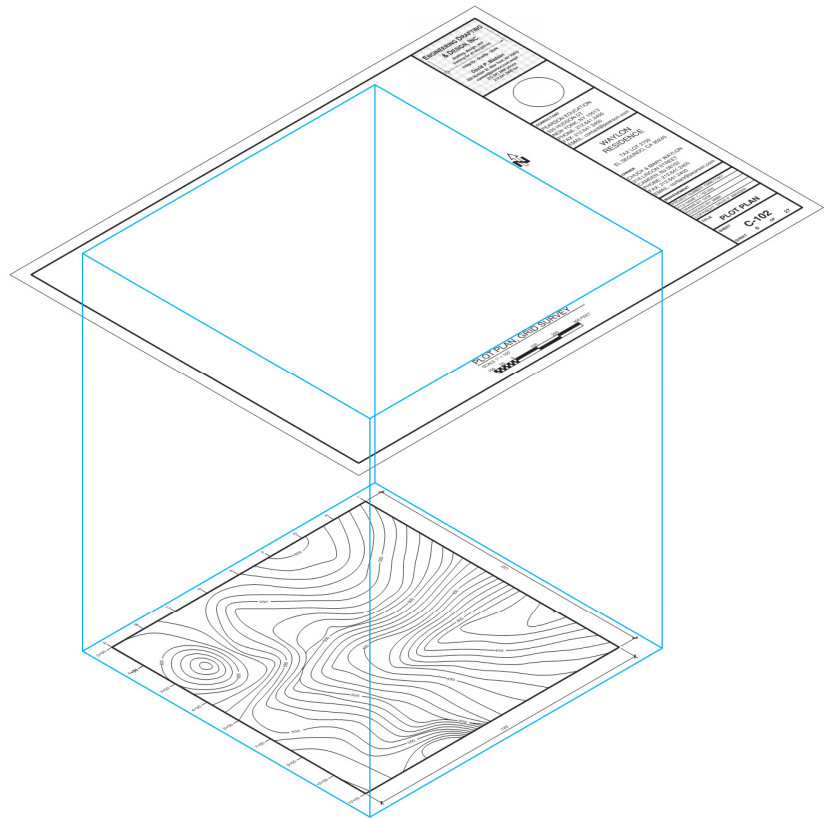
Figure 2-22. Examples of NCS sheet names.

Plotting

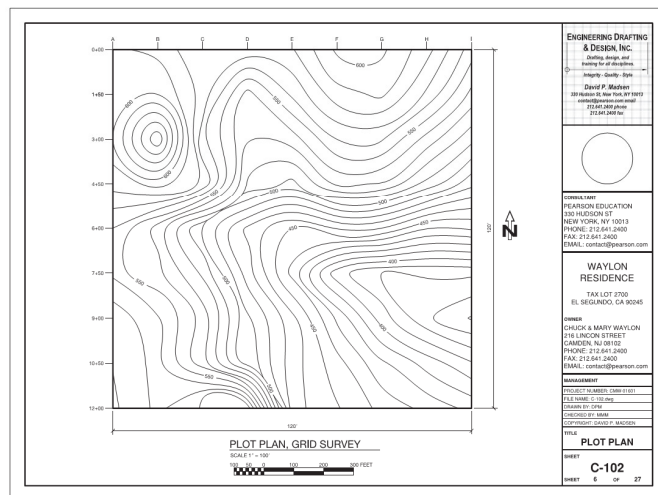
A drawing created in CADD initially exists as a soft copy. A **soft copy** is the electronic data file of a drawing or model. A **hard copy** is a physical drawing created on paper or some other media by a printer or plotter. Hard copies are often a required element of the engineering or construction process, and they are usually more useful at a construction site than soft copies. A design team can check and redline a hard copy without a computer or CADD software. CADD is the standard throughout the world for generating drawings, and electronic data exchange is becoming increasingly popular. However, hard-copy drawings are still a vital tool for communicating a design.

Each CADD system uses a specific method to plot, though the theory used in each is similar. In general, you must select the plot device, plot device properties, sheet size and orientation, area to plot, drawing scale, number of copies, and other software and drawing specific settings. A **plot device** is the printer, plotter, or alternative plotting system to which the drawing is sent. The drawing **scale** refers to the ratio of measuring units expressing a proportional relationship between a drawing and the full-size items the drawing represents. Chapter 3 explains scale in more detail.

Some CADD applications highly automate plotting, especially the process of scaling a drawing for plotting. Other systems require you to follow specific procedures to scale a plot correctly and efficiently. AutoCAD, for example, uses the model space and paper space system. **Model space** is the environment in which you create drawings and designs at full scale. **Paper space**, or **layout**, is the environment in which you prepare the final drawing for plotting to scale. The layout often includes items such as viewports to display content from model space, a border, sheet blocks, general notes, tables, sheet annotation, and sheet setup information (see Figure 2-23).



(a)



(b)

Figure 2-23. (a) The concept of using model space to prepare dimensioned drawing views and paper space to scale the model space drawing and add sheet content for plotting. (b) Model space combined with paper space to create the final drawing with viewport boundaries hidden.

Scale Factor

When drawing with CADD, always draw objects at their actual size, or full scale, regardless of the size of the objects. For example, if you draw an airport runway that is 6,000' long, draw the runway 6,000' long. This example describes drawing objects that are too large for layout and printing purposes. Scale the objects to fit properly on a sheet, according to a specific drawing scale. When you scale a drawing, you increase or decrease the displayed size of objects. AutoCAD, for example, uses model space and paper space for this process. Scaling a drawing greatly affects the display of items added to full-scale objects such as annotations, because these items should be the same size on a plotted sheet, regardless of the displayed size, or scale, of the rest of the drawing.

Scale factor is the reciprocal of the drawing scale, and is used in the proper scaling of various objects such as text, dimensions, and graphic patterns. Most CADD software automates the process of scaling a drawing, allowing you to focus on choosing a scale rather than calculating the scale factor. However, scale factor is a general concept with which you should be familiar, and it remains an important consideration when working with some CADD applications.

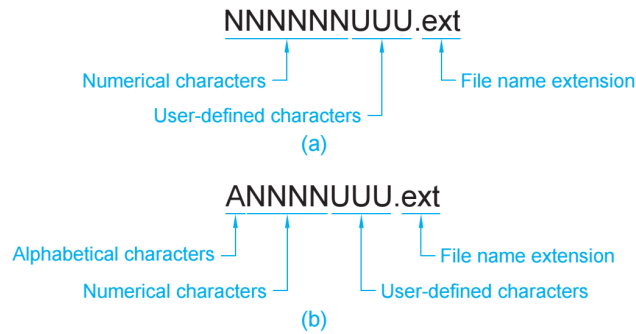
Traditional manual scaling of annotations, graphic patterns, and other objects requires determining the scale factor of the drawing scale and then multiplying the scale factor by the plotted size of the objects. Text is a convenient object to describe the application of scale factor. For example, to plot text that is 1/8" high on a drawing plotted at a scale of 1/4" = 1'-0", multiply the scale factor by 1/8". The scale factor is the reciprocal of the drawing scale. A 1/4" = 1'-0" scale drawing has a scale factor of 48 ($1'-0" \div 1/4" = 48$). Multiply the scale factor of 48 by the text height of 1/8" to find the 6" scaled text height. The proper height of 1/8" text in an environment such as model space at a 1/4" = 1'-0" scale is 6".

Electronic Plots

Exporting is the process of transferring electronic data from a database, such as a drawing file, to a different format used by another program. Exporting a drawing is an effective way to display and share a drawing for some applications. One way to export a drawing is to plot a sheet to a different file type. Electronic plotting uses the same general process as hard-copy plotting, but the plot exists electronically instead of on an actual sheet of paper.

A common electronic plotting method is to plot to a portable document format (PDF) file. For example, send a PDF file of a layout to a contractor, agency, or plotting service. The recipient uses Adobe software to view the plot electronically and plot the drawing to scale without having CADD software, thus avoiding inconsistencies that sometimes occur when sharing the CADD files. Another example is plotting an AutoCAD file to a design web format (DWF) file. The recipient of a DWF file uses a viewer such as Autodesk Design Review software to view and mark up the plot.

Figure 2–24. (a) The MasterFormat library file naming system. (b) The UniFormat library file naming system.



File Organization

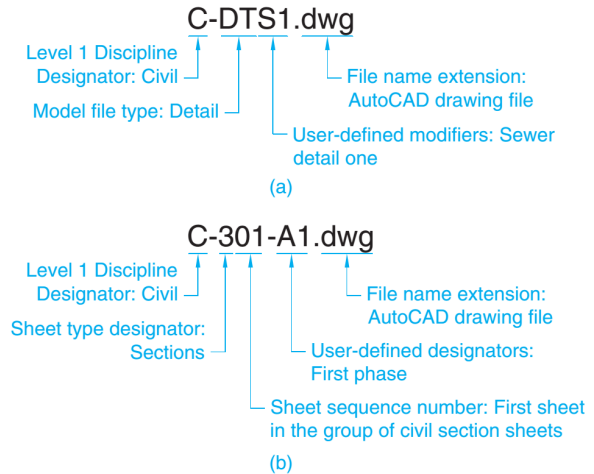
Files must be organized so that data is secure and so that anybody working on a project can easily find data when needed. Develop an organized structure of file folders, and use subfolders as needed to help organize each project. The files in each project subfolder can include drawing files, word processing documents, and spreadsheets, as needed. This system helps keep the entire project together, making it easier to manage. File management practices vary greatly depending on the established standards and project, drawing, and software requirements. A standard folder and file naming system allows you to find files quickly and easily by content, category, or other criteria.

The name you assign to a file is one of several file properties. File naming is typically based on a specific system associated with the project and approved drawing standards. A file name should be concise and allow you to determine the content of the file. The NCS Uniform Drawing System, Drawing Set Organization module includes detailed project file and folder organization and naming recommendations. The system groups files as library or project files. **Library files** are files that include standard content used for many different projects, such as border, title block, and detail files. The NCS recommends using the MasterFormat or UniFormat library file naming system (see Figure 2–24). For more information about MasterFormat and UniFormat, go to www.csinet.org or www.csc-dcc.ca.

Project files are files that apply to individual projects, and are categorized as model, detail, sheet, schedule, text, database, symbols, border, and title block files. The NCS specifies a file naming system for each type of project file. This chapter focuses on model and sheet files. A **model file** contains the full-scale drawing or model with individual elements that make up the design, such as the property lines, buildings, utilities, and roadways on a site plan. A **sheet file** is a file that brings model files and the border, title block, and other sheet content together to create a drawing for plotting. Figure 2–25 provides an example of a model and sheet file name.

Sheet files reference model files. Referencing an external file allows you to use data from source files rather than storing it in the host drawing. This technique helps multiple users share content and minimizes file size. Another advantage of using external references is the link between reference and host files. Any changes you make

Figure 2-25. (a) An example of a model file name. (b) An example of a library file name. Examples of file name extensions are dgn, dwg, dwf, dxf, and rvt.



to reference files are reflected in host drawings, so the host drawings display the most recent reference content.

File Management Guidelines

Your use of CADD files can be as basic as opening a drawing file, working on it, and saving it in the same location. You might also be responsible for creating new folders and subfolders for new projects and managing files. Understanding proper file management techniques allows you to maximize the potential of your workstation and saves you time when working in CADD. Consider the following guidelines when managing files:

- Create storage media directories and folders for all files.
- Never save your working files in folders that contain program files.
- Create a separate folder for each project and subfolders for different types of files in the project.
- Store template files in a protected location that allows only selected individuals to edit and save these files.
- Keep drawing files separate from files such as text documents, spreadsheets, and database files.
- Maintain off-site locations for file storage and archiving.
- Establish a regular schedule for deleting all backup and temporary files from your storage media.
- Use tools such as AutoCAD's blocks and external references to help keep drawing size at a minimum.
- Purge, or remove, unreferenced data from the drawing. For example, purge layers that have not been assigned to objects.
- Use hard disk management software to rearrange software and data on the hard disk to reclaim space occupied by deleted files.
- Install only licensed software on your computer system. It is illegal to use unlicensed software.
- Never install software without approval from your supervisor or instructor.

Designing and drafting effectively with a computer requires a skilled CADD operator. To be a proficient CADD software user, you must have detailed knowledge of CADD commands and processes, and know which command and process is best suited for a specific task. Your worth as a drafter is determined by the amount of work you can complete during a given time, and the quality and accuracy of your work. A successful drafter carefully plans the tasks required to achieve the end result, and eliminates as many unneeded actions as possible. Learn commands, tools, and options that increase your speed and efficiency, and learn to use available resources to help solve problems and answer questions.

Planning Your Work

Carefully plan your work and think ahead to prepare for each stage of the time you spend working on a drawing project. A drawing plan involves thinking about the entire process or project in which you are involved. Your drawing plan focuses on the content you want to present, the objects and symbols you intend to create, and the appropriate use of standards. You may want processes to be automatic or to happen immediately, but if you hurry and do little or no planning, you may become frustrated and waste time while drawing. Take as much time as needed to develop drawing and project goals so that you can proceed with confidence.

Saving Your Work

Store drawings on your computer or a network drive according to school or company practice. Drawings are lost due to software error, hardware malfunction, power failure, or accident. Prepare for such an event by saving your work frequently. Develop a habit of saving your work at least every 10–15 minutes. Your software may have an automatic save option to save drawings automatically at set intervals. However, you should also frequently save your work manually. Back up files to a removable storage device, online service, or other system to help reduce the possibility of permanently losing information during a system failure.

Reusing Drawing Content

The drawings created for a given project generally have the same set of standards, and may share a number of common elements. You often duplicate drawing content, such as layers, text and dimension settings, symbols, details, and model files in many different drawings. **Drawing content** is all of the objects, settings, and other components that make up a drawing. One of the fundamental advantages of CADD is the ease with which you can share content between files. Once you create a common drawing element, you can reuse the item as needed in any number of drawings.

One method to reuse drawing content is to seek out data from existing files. This is a common requirement when you develop

related drawings for a specific project or work on similar projects. Sharing drawing content is also common when revising drawings and when duplicating standards used by a contractor or client. Most CADD software provides several ways to share drawing content. You can generally reuse existing content by applying a copy and paste, or drag-and-drop type of operation.

Template Drawings

You typically begin a new drawing by referencing a **drawing template**, or **template**, file. A drawing template automates the process of using an existing drawing as a starting point for a new drawing. A template includes drawing settings and objects for specific applications that are preset each time you begin a new drawing. Templates are incredible productivity boosters, and can help ensure that everyone at your school or company uses the same drawing standards. Templates usually include the following elements, set according to the drawing requirements:

- Units and drawing area
- Drawing aids to increase efficiency
- Layers with specific line conventions
- Text, dimension, table, and other annotation styles
- Sheet file and plot settings
- Common symbols and details

Note: The Digital Resources for this textbook contain several predefined AutoCAD drawing templates that you can use to create drawings in accordance with correct drafting standards. The templates are loaded with drawing content including layers; text, dimension, table, and multileader styles; and layouts with sheet blocks for various sheet sizes. Go to www.pearsonhighered.com/careersresources/ and navigate to this textbook and chapter to locate and download the templates.

Ergonomics

Ergonomics is the science of adapting the work environment to suit the needs of the worker. There is concern about the effects of the CADD working environment on the individual worker. Some studies have found that people should not work at a computer workstation for longer than about four hours without a break. Physical problems, ranging from injury to eyestrain, can develop when someone is working at a poorly designed CADD workstation. The most common injuries are repetitive motion disorders, which include repetitive strain injury (RSI), repetitive movement injury (RMI), cumulative trauma disorder (CTD), and occupational overuse syndrome (OOS). Carpal tunnel syndrome is a common repetitive motion disorder. Most computer-related injuries result from the sedentary nature of working at a computer and the fast, repetitive hand and finger motions typical while using keyboards and pointing devices. Proper workstation ergonomics, good posture, and frequent exercise help to prevent most computer-related injuries.

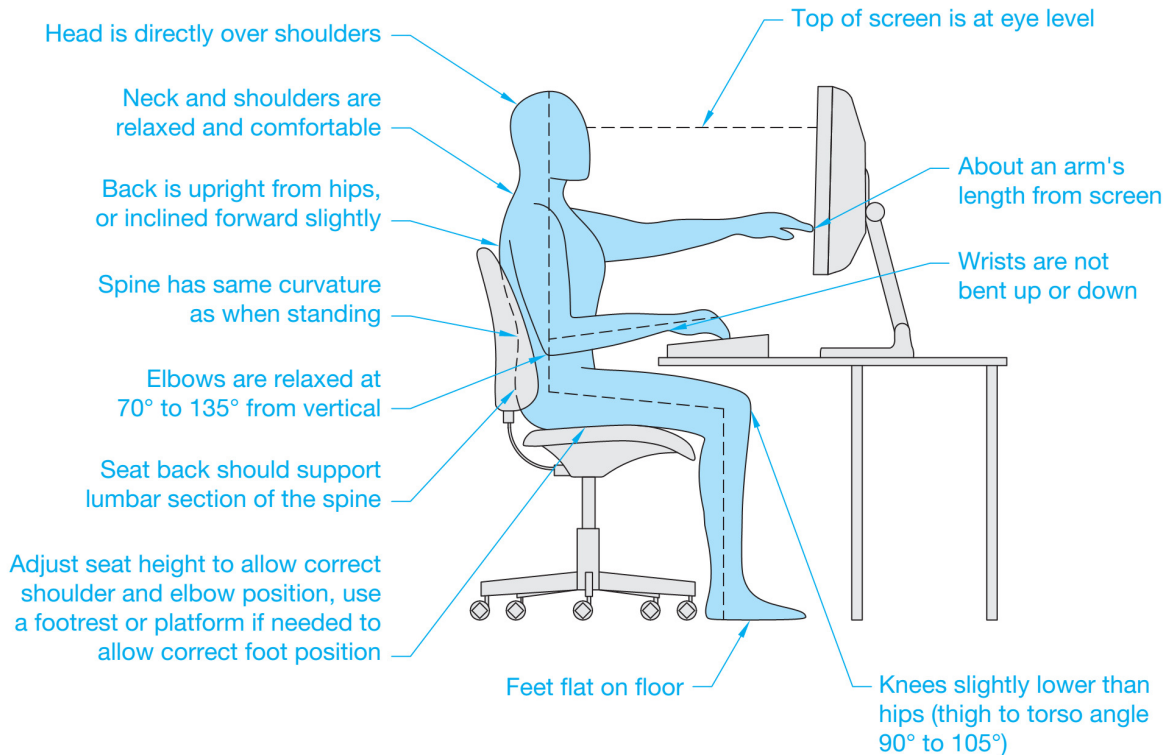


Figure 2-26. An ergonomically designed workstation.

Ergonomic Workstations

Figure 2-26 shows an ergonomically designed workstation. In general, a workstation should be designed so that you sit with your feet flat on the floor, your calves perpendicular to the floor, and your thighs parallel to the floor. Your back should be straight, your forearms should be parallel to the floor, and your wrists should be straight. For some people, the keyboard should be either adjustable or separate from the computer to provide more flexibility. The keyboard should be positioned, and arm or wrist supports can be used, to reduce elbow and wrist tension. In addition, when the keys are depressed, a slight sound should be heard to ensure the key has made contact. Ergonomically designed keyboards are available.

The monitor should be 18"–28", or approximately one arm's length, away from your head. The screen should be adjusted to 15°–30° below your horizontal line of sight. Eyestrain and headache can be a problem with extended use. If the position of the monitor is adjustable, you can tilt or turn the screen to reduce glare from overhead or adjacent lighting. Some users have found that a small amount of background light is helpful. Monitor manufacturers offer large, flat, nonglare screens that help reduce eyestrain. Some CADD users have suggested changing screen background and text colors weekly to give variety and reduce eyestrain.

The chair should be designed for easy adjustments to give you optimum comfort. It should be comfortably padded. Your back should be straight or up to 10° back, your feet should be flat on the floor, and your elbow-to-hand movement should be horizontal when you are using the keyboard, mouse, or digitizer. The mouse or digitizer puck should be close to the monitor so movement is not strained and equipment use is flexible. You should not have to move a great deal to look directly over the cursor to activate commands.

Positive Work Habits

In addition to an ergonomically designed workstation, your own personal work habits can contribute to a healthy environment. Try to concentrate on good posture until it becomes second nature. Keeping your feet flat on the floor helps improve posture. Try to keep your stress level low, because increased stress can contribute to tension, which can aggravate physical problems. Take breaks periodically to help reduce muscle fatigue and tension. Exercise to help reduce workstation-related problems. Some people also have success with yoga, biofeedback, and massage. Consult your doctor, physical therapist, exercise professional, or personal trainer for advice and recommendations on positive work habits and exercise.

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Define the following terms.

2-1 Computer-aided design and drafting (CADD)

2-2 Virtual

2-3 Line work

2-4 Line conventions

2-5 Layer

2-6 General notes

2-7 Specific notes

2-8 Delta note

2-9 Specifications

2-10 Dimensions

2-11 Symbol library

2-12 Parameter

- 2-13** Soft copy
- 2-14** Hard copy
- 2-15** Scale factor
- 2-16** Model file
- 2-17** Sheet file
- 2-18** Drawing content
- 2-19** Drawing template
- 2-20** Ergonomics

Part 2

Choose the response that best describes each statement.

- 2-21** A unified sequence of processes through which a project passes from initiation to operation describes:
 - a.** Building information modeling (BIM)
 - b.** Computer-aided drafting (CAD)
 - c.** Computer-aided engineering (CAE)
 - d.** Machine control
- 2-22** Text-based data assigned to a specific object is known as:
 - a.** Material take off (MTO)
 - b.** Attributes
 - c.** Drafting standards
 - d.** CADD symbols

2-23 Line convention are the standards related to line:

- a. Weight
- b. Type
- c. Purpose
- d. All of the above

2-24 ASME standards recommend which line thicknesses:

- a. 0.005" (0.13 mm) and 0.007" (0.18 mm) extra fine lines
- b. 0.005" (0.13 mm) extra fine and 0.010" (0.25 mm) thin lines
- c. 0.02" (0.6 mm) thick and 0.01" (0.3 mm) thin lines
- d. 0.014" (0.35 mm) medium and 0.020" (0.50 mm) wide lines

2-25 An example of an AIA CAD Layer Guidelines layer name is:

- a. V_Object
- b. C-ANNO
- c. HIDDEN
- d. C-301.dwg

2-26 The minimum height for text on a drawing as specified by the NCS is:

- a. 1/8"
- b. 1/4"
- c. 1/16"
- d. 3/32"

2-27 Notes that apply to an entire drawing are called:

- a. Specific notes
- b. General notes
- c. Delta notes
- d. Key notes

2-28 Specific notes are also referred to as:

- a. Exact
- b. Detailed
- c. Local
- d. General

- 2-29** If the height of standard text on a drawing is 1/8", how tall should dimensions and notes be:
- a. 1/4"
 - b. 1/16"
 - c. 1/8"
 - d. 1/2"
- 2-30** Template drawing typically includes:
- a. Units
 - b. Layers
 - c. Annotation styles
 - d. All of the above

PROBLEMS

Follow the specific instructions to complete each problem.

- P2-1** Describe one example of building information modeling (BIM) for civil engineering.
- P2-2** Describe each of the four major components of the U.S. National CAD Standard (NCS).
- P2-3** Describe three ways layers can increase productivity and add value to a drawing.
- P2-4** Research and write a report of approximately 250 words describing the U.S. National CAD Standard (NCS).
- P2-5** Research and write a report of approximately 250 words describing a civil CADD software product.
- P2-6** Research and write a report of approximately 250 words describing the CADD system and workstation. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.

P2-7 Research and write a report of approximately 250 words describing the differences among inkjet plotters and laser printers. Prepare a PowerPoint presentation of your research and present the slide show to your class or office. Include the following points in your report:

- Type of media required, such as paper and ink
- Media size
- Purchase and operational cost
- Quality of final print or plot
- Usefulness in your application
- Warranties and service contracts
- Durability
- Reputation
- Length of time on the market

P2-8 Create a specification sheet for the purchase of a current single CADD workstation, operating system software, word processing software, spreadsheet software, and civil CADD software for use on the computer. Itemize the cost of each component and establish a total price. Obtain at least two competitive quotes. Prepare a PowerPoint presentation of your research and present the slide show to your class or office. This assignment should include the following elements in addition to information found in your research:

- Computer memory
- Processor speed
- Hard drive capacity
- Portable or built-in storage media
- Graphics card
- Ports
- Monitor
- Input device
- Printer or plotter
- Operating system
- Civil CADD software
- Word processing software
- Spreadsheet software

P2-9 Draw each line shown in Figure 2-7. Print or plot your drawing.

P2-10 Draw each note shown in Figure 2-12. Print or plot your drawing.

P2-11 Draw an example of a list of at least five civil drafting general notes.

P2-12 Draw an example of at least three civil drafting specific notes.

- P2-13** Draw the notes shown in Figure P2-13 using Arial font and a 0.12" and 0.20" text heights. Copy the paragraph and change the font assigned to the copied paragraph to Stylus BT and the height to 1/8" and 1/4".

Text is the lettering on a CADD drawing. Consistent text type, format, height, and spacing are critical to legibility and drawing clarity. CADD provides commands and settings to create uniform, easy-to-read text according to drafting standards. A variety of text styles and fonts are available, and text commands and options provide great control over text composition. Font is the face design of a letter or number. The style of text used on civil drawings varies depending on the established standards and project requirements, but plain vertical text is most common. Some architectural and civil engineering companies prefer a more traditional architectural hand-lettering appearance for text.

Figure P2-13.

- P2-14** Draw the tables shown in Figure 2-17. Print or plot your drawing.

- P2-15** Design a CADD workstation including, but not limited to a computer, monitor, keyboard, and pointing device. Take measurements of existing computer equipment and use vendor catalogs to develop your design. Draw views of the complete workstation, including the table and computer equipment.



CHAPTER

3

Map Scales

Learning Objectives

After completing this chapter, you will be able to:

- Define scale and scale factor.
- Explain numerical scale.
- Create and use graphic scales.
- Convert representative fractions to graphic scales.
- Convert graphic scales to representative fractions.
- Explain verbal scale.
- Use scales to take measurements.
- Apply basic CADD scale techniques.

Key Terms

Scale
Map
Numerical scale
Representative fraction (RF)
Numerator
Denominator
Graphic scale
Scale bar
Mechanical divider
Divider
Verbal scale
Engineer's scale
Metric scale
Zoom
Model space
Paper space
Layout
Model
Floating viewport
Scale factor
Limits

Scale refers to the ratio of measuring units expressing a proportional relationship between a drawing and the full-size items the drawing represents. A scale is also an instrument with a system of ordered marks at fixed intervals used for measurement. A scale establishes a proportion that is used to determine the dimensional relationship of an actual object to the representation of the same object on a drawing. This chapter explains the purpose and types of map scales.

Map Scale

A **map** is a graphic representation of part or all of the Earth's surface, drawn to scale on a plane surface. A map's scale allows you to estimate distances and determines the amount of detail displayed on a map. Selecting the appropriate scale depends on the size of the geographical area, the amount of required detail, and the size of the area on which the map is drawn. A map of the State of New York painted to scale on a large, blank wall of a building uses a different scale than the same map drawn to scale on a 24" × 18" (architectural C) size sheet of paper. A map of your school or office building drawn on a page in this textbook will have a different scale than a map of the United States drawn on the same page.

A small-scale map shows a large area, while a large-scale map shows a small area. Some of the smallest-scale engineering drawings are in the civil engineering field. Civil engineering drawings are commonly scaled in multiples of 10 feet (') to 1 inch ("), such as 1" = 10', 1" = 20', 1" = 100', and 1" = 5,000'. A scale stated as 1" = 10', for example, means that every 1" on the drawing represents 10'. Sometimes civil drawings are scaled using a system common for architectural applications, where a fraction of one inch equals one foot. For example, an architectural scale specified as 1/2" = 1'-0" means that every 1/2" on the drawing represents one foot. Metric scales are designated by the amount by which they reduce or enlarge the original objects. For example, a metric scale stated as 1:2 means that the objects are reduced to 1/2 (0.5 or 50%) of the original size. A common metric civil drawing scale is 1:200, which means a 1/200 (0.005) scale reduction. Scales can be expressed using a numerical scale or represented fraction, graphic scale, or verbal scale as explained in the following sections.

Numerical Scale

A **numerical scale** gives the proportion between the length of a line on a map and the corresponding length on the Earth's surface, known as the **representative fraction (RF)**. An RF equals the distance on a map ÷ the distance on the Earth (RF = distance on map/distance on the Earth), using the same units of measure. The first number is the **numerator**, which is the number above the fraction bar, and represents the map. The RF numerator is always one; a single unit of measure equal to the distance on the map. The second number is the **denominator**, which is the number below the fraction bar, and

represents the ground. The denominator is always greater than the numerator because it represents the distance on the Earth. An RF can be written as a fraction such as $1/150,000$, or as a ratio such as $1:150,000$.

A numerical scale always refers to map and ground distances in the same unit of measure. The unit of measure most commonly used in an RF is the inch. For instance, a scale of 1" on a map representing 1 mile (mi.) on the Earth's surface is expressed as $RF = 1/63,360$ or $1:63,360$ because 1 mi. equals 63,360". The larger the denominator is, the smaller the scale will be. A map with a small scale and large RF denominator, drawn on a specific size of paper, shows more of the Earth's surface than a map with a large scale and small RF denominator, drawn on the same size of paper (see Figure 3-1).

To calculate the distance between two points on a map, multiply the measured distance in inches by the RF denominator. For example, if you measured $2\frac{1}{4}"$ between points A and B on a map drawn to a scale of $1/100,000$, the distance on the Earth between points A and B is: $Distance = 2\frac{1}{4}" \times 100,000" = 225,000"$ or $18,750'$ ($225,000" \div 12" \text{ per foot} = 18,750'$). If the map is calibrated in metric units, $1:100,000$ means 1 centimeter (cm) = 100,000 cm = 1 kilometer (km).

Small-Scale and Special Maps

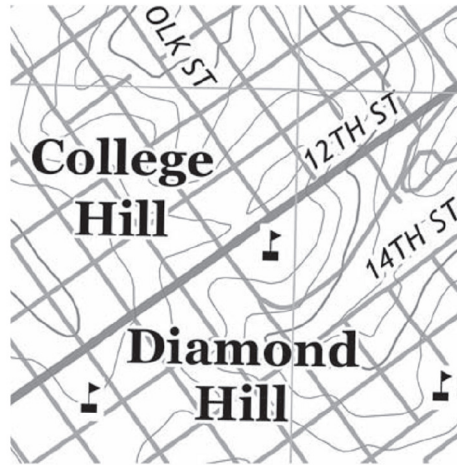
You will explore maps and drawings created at a variety of different scales throughout this textbook. The following list identifies some of the small-scale and special maps published to meet modern requirements. For more information about small-scale and special maps, go to the U.S. Geological Survey website at www.usgs.gov.

- $1:250,000$ scale maps (1" on the map represents about 4 mi. on the ground)—For regional planning and as topographic bases for other types of maps.
- $1:500,000$ scale state maps (1" on the map represents 8 mi. on the ground)—For use as wall maps and for statewide planning.
- Various scale shaded relief maps—For park management and development and as tourist guides.
- Various scale Antarctic topographic maps—For scientific research.
- $1:1,000,000$ scale International Map of the World (IMW)—For broad geographic studies.

Graphic Scale

A **graphic scale** is a symbol, located in the field, legend, or margin of a sheet, with a system of ordered marks at fixed intervals used for measurement. A graphic scale is sometimes referred to as a **scale bar** and is common on maps and civil engineering drawings. The divisions on the graphic scale represent increments of measure easily applied to the map. The NCS Uniform Drawing System, Symbols module includes examples of standard graphic scales.

Small RF denominator =
Large scale



RF: 1:24,000
Scale: 1 inch = 2,000 feet
Area shown: 1/2 square mile



RF: 1:63,360
Scale: 1 inch = 1 mile
Area shown: 1.32 square miles



RF: 1:250,000
Scale: 1 inch ≈ 4 miles
Area shown: 5.21 square miles

Figure 3-1. A graphic example of maps created at different scales.
(Maps courtesy of the U.S. Geological Survey)

However, the appearance of graphic scales varies greatly depending on company and project standards, and the CADD software used. Typically, graphic scales consist of two or three segments that correspond to specific increments of measure. Above or below the segment edges are numbers that define the increments of measure, and usually one or more of the numbers identify the unit of measure. Graphic scales normally begin at zero, but many have an extension to the left of the zero that allows you to determine distances less than the major unit of the scale. A graphic scale uses relatively even units of measure, such as 500 or 1,000. Figure 3–2 shows examples of graphic scales.

There are a number of techniques for using graphic scales. You can use a graphic scale as a quick reference by visually comparing the graphic scale to features on the map, or you can approximate a distance on the map using your fingers to transfer map measurements to the graphic scale. To use your fingers, create a space between your thumb and forefinger that matches a desired distance on the map. Keeping the space between your thumb and forefinger constant, move your fingers to the graphic scale and read the measurement of the same distance on the graphic scale. To take a more accurate measurement, use mechanical dividers to associate distances on the graphic scale to map features. A **mechanical divider**, also referred to as a **divider**, is a drafting instrument consisting of two pointed legs, pivoted together at one end and used for transferring distances. Another option is to use a piece of paper to reference distances on the map. For example, to measure the

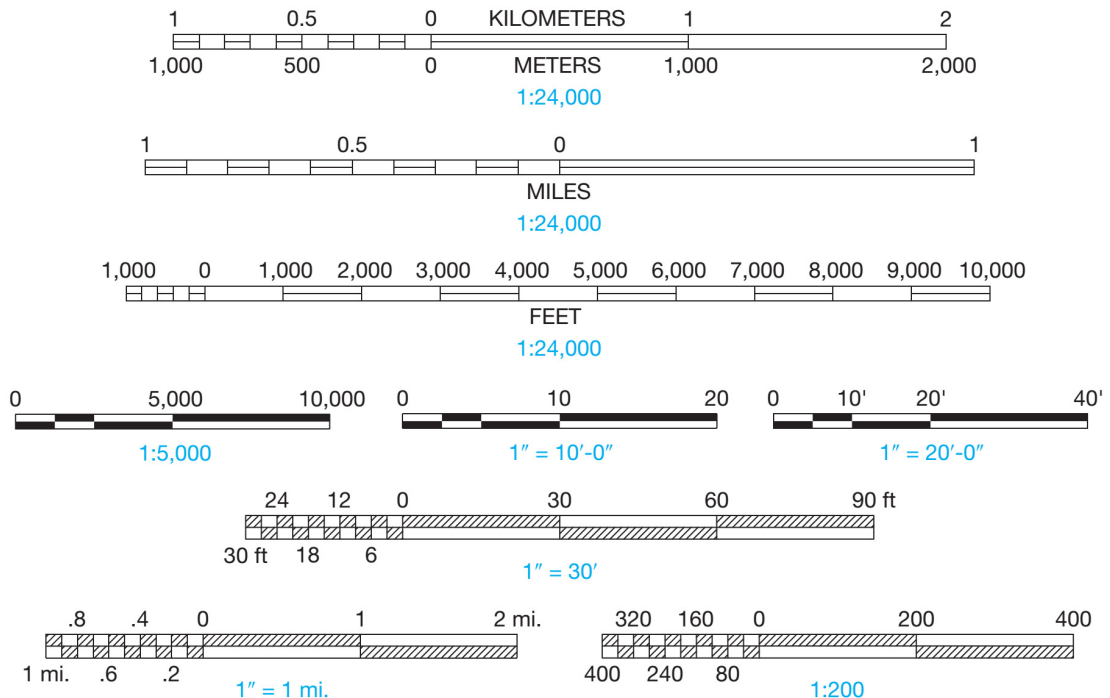


Figure 3–2. Examples of graphic scales. The 1:5,000, 1" = 10'–0", and 1" = 20'–0" graphic scales use the NCS recommended format.

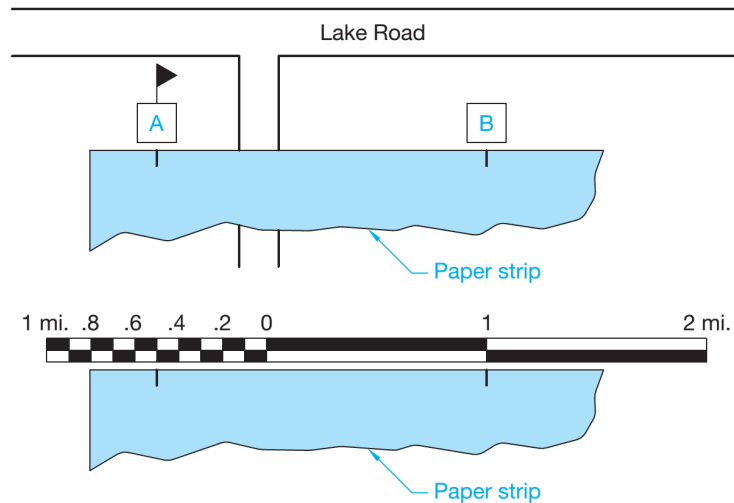


Figure 3-3. Measuring with a graphic scale.

distance on a road between points A and B on the map shown in Figure 3-3, apply a straight-edged strip of plain paper on the map along the distance between the two points and make marks on the paper strip where the edge touches A and B. Then move the strip of paper to the graphic scale and measure. Point A is found to be 1.5 mi. from point B.

Converting an RF to a Graphic Scale

In map drafting and reading, it is often necessary to convert from one scale to another. You may have to convert an RF scale to a graphic scale for display on a map. The following is an example of how to convert an RF to a graphic scale. You must identify components of the conversion equation based on the RF, the size of the geographic area, the amount of detail required, and the size of the sheet on which the map is drawn. Use the following example to understand the conversion process and as a model for converting other RFs to graphic scales.

Example: Find the graphic equivalent to a 1:300,000 RF. First, remember that the 1 equals 1" on the map, and the 300,000 equals 300,000" on the Earth's surface. Now determine the number of miles that are represented by 300,000". Make the following calculation based on the fact that there are 63,360" in a mile:

$$\frac{300,000" \text{ on the Earth}}{1} \times \frac{1 \text{ mi. on the Earth}}{63,360" \text{ on the Earth}} = 4.73 \text{ mi. on the Earth}$$

Therefore, 1" on the graphic scale equals 4.73 mi. on the Earth's surface. This scale is not practical because it is difficult to imagine odd measurements such as 4.73 mi. (see Figure 3-4). Instead, graphic scales are drawn using units like 0-1-2-3-4, 0-2-4-6, or 0-5-10-15-20. It is necessary to find out how many inches are used to show any even number larger than the 4.73 mi. previously



Figure 3-4. This graphic scale is not practical because it is difficult to imagine the odd measurements shown.

determined. For example, use 10 mi. This would be set up in the following ratio:

$$\begin{aligned}\frac{4.73 \text{ mi.}}{1''} &= \frac{10 \text{ mi.}}{\text{unknown no. of inches (x)}} \\ 4.73x &= 10 \\ x &= 2.11''\end{aligned}$$

The solution to this formula means that there are 2.11" in 10 mi. Once you generate this information, you can create a graphic scale by drawing 2.11" segments. Then, divide the left segment into 10 equal parts to provide distances less than the major unit of scale; in this case, each division equals 1 mi. Remember, in this example, each 2.11" segment represents 10 mi. on the map. Figure 3-5 shows a graphic scale created based on the previous example. This graphic scale consists of three 2.11" segments, with the left segment divided into 10 equal parts.

Converting a Graphic Scale to an RF

Example: Find the RF given that 1" on the graphic scale of a map equals 5 mi. Make the following calculation based on the fact that there are 63,360" in a mile:

$$\begin{aligned}\frac{5 \text{ mi. on the Earth}}{1} \times \frac{63,360'' \text{ on the Earth}}{1 \text{ mi on the Earth}} &= \\ 316,800'' \text{ on the Earth's surface} & \\ \text{RF} = 1:316,800 &\end{aligned}$$

Example: Determine the RF for a map with no scale. To find the RF, measure the length of 1° of latitude along a meridian of the map. Chapter 6 explains latitude, but for now, know that an angle of 1° of latitude is about 69 mi. Make the following calculation to convert 69 mi. to inches:

$$\begin{aligned}\frac{69 \text{ mi. on the Earth}}{1} \times \frac{63,360'' \text{ on the Earth}}{1 \text{ mi. on the Earth}} &= \\ 4,371,840'' \text{ on the Earth's surface} & \\ \text{RF} = 1:4,371,840 &\end{aligned}$$

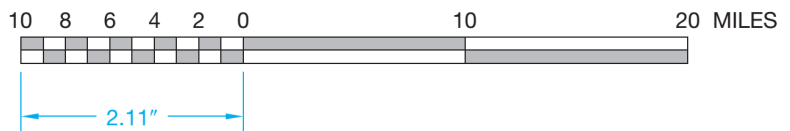


Figure 3-5. Correct graphic scale with one segment divided into 10 equal spaces. The 2.11" dimension is for reference only.

Suppose the length of 1° of latitude on the map is 2.3". Then, because the RF is the ratio of 1" on the map to the number of inches on the Earth's surface, use the following calculation:

$$\text{RF} = \frac{\text{in. on the map}}{\text{in. on the Earth}} = \frac{2.3}{4,371,840}$$

Reduce the ratio by dividing the numerator and denominator by 2.3 as shown in the following calculation:

$$2.3 \div 2.3 = 1$$

$$4,371,840 \div 2.3 = 1,900,800$$

$$\text{RF} = 1:1,900,800$$

Verbal Scale

Verbal scale is a close approximation of scale for discussion purposes only. Verbal scale is often expressed in the number of inches to the mile. Usually, the mileage is rounded. For example, 1" on an RF scale of 1:1,000,000 equals 15.78 mi. This distance expressed in verbal scale rounds off the 15.78 mi. to 16 mi. The verbal scale in this example is 1" = 16 mi. Verbal scale is only a rough estimate and not meant to be accurate. Use the RF scale, graphic scale, or a numbered grid system on the map for accurate measurements.

Scale Tools

The term scale also describes an instrument with a system of ordered marks at fixed intervals used for measurement. Scales are available in different calibrations and a variety of lengths and shapes. Rigid flat, bevel, and triangular scales; and flexible tape scales are most common. The scale was once the principal tool for drawing maps and drawings to scale. Today, scales continue to be useful tools, allowing you to:

- Read, measure, and understand existing maps and plans that are drawn to scale.
- Check the scale accuracy of a CADD plot.
- Prepare sketches and archival drawings to scale.

Engineer's Scale

An **engineer's scale** is a decimal U.S. customary (inch) scale calibrated in multiples of 10. Figure 3–6 shows a triangular engineer's scale. There are six scales found on a triangular engineer's scale. The 10 on one edge along the margin of the engineer's scale shown in Figure 3–6 identifies the 10 scale and is calibrated in multiples of parts per inch. The other edges have the 20, 30, 40, 50, and 60 scales (see Figure 3–7). Measurements are easy to multiply and divide because they are given in decimals rather than in feet and inches. Figure 3–8 illustrates how to use the engineer's scale to measure distances.

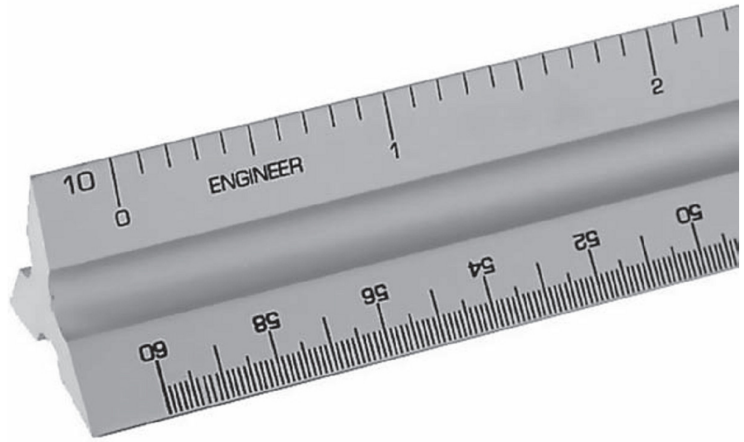


Figure 3-6. A portion of a triangular engineer's scale.

Scale	Ratio	Example Map Scales		
10	1:1	1" = 1'	1" = 10'	1" = 100'
20	1:2	1" = 2'	1" = 20'	1" = 200'
30	1:3	1" = 3'	1" = 30'	1" = 300'
40	1:4	1" = 4'	1" = 40'	1" = 400'
50	1:5	1" = 5'	1" = 50'	1" = 500'
60	1:6	1" = 6'	1" = 60'	1" = 600'

Figure 3-7. The triangular engineer's scale includes 10, 20, 30, 40, 50, and 60 scales.

Metric Scale

A **metric scale** is a decimal International System of Units (SI) scale calibrated in multiples of 10. Figure 3-9 shows a triangular metric scale. A triangular metric engineer's scale provides 1:1, 1:2, 1:5, 1:10, 1:20, and 1:50 calibrations. A triangular metric architect's scale provides 1:100, 1:200, 1:250, 1:300, 1:400, and 1:500 calibrations. A triangular metric mechanical scale offers 1:20, 1:25, 1:50, 1:75, 1:100, and 1:125 calibrations. The unit of measure commonly used in metric scales is the millimeter (mm). Figure 3-10 shows metric unit abbreviations. Metric scales are convenient to work with because they are calibrated in units of 10, which makes metric-to-metric conversions easy. Figure 3-11 illustrates how to use the metric scale to measure distances.

Figure 3-12 lists metric-to-metric conversions, common metric-to-U.S. customary equivalents, and common U.S. customary-to-metric equivalents. Figure 3-13 displays common map scales and their U.S. customary and metric equivalents. The following is the most common inch-to-metric conversion formula:

$$\text{inches} \times 25.4 = \text{mm}$$

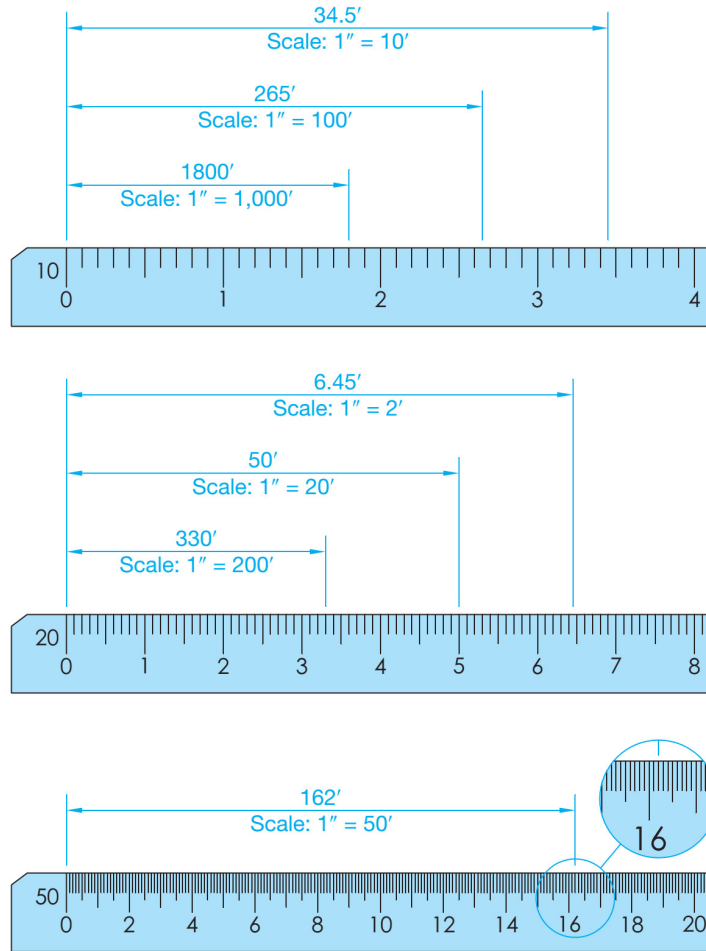


Figure 3-8. Examples of margins and scales on an engineer's scale.

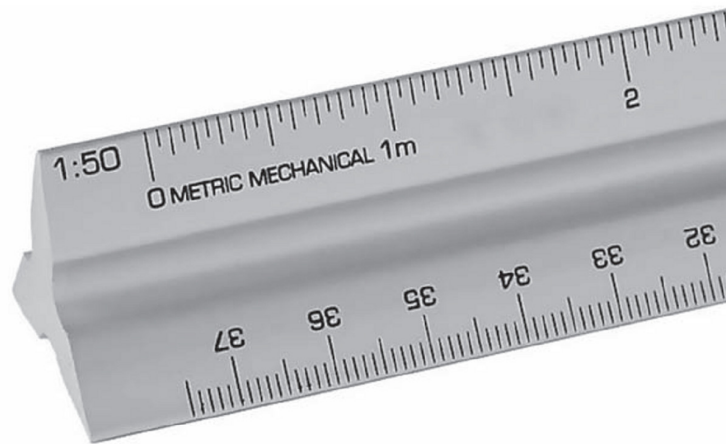


Figure 3-9. A portion of a triangular metric scale.

Unit	Abbreviation
millimeter	mm
centimeter	cm
decimeter	dm
meter	m
dekameter	dam
hectometer	hm
kilometer	km

Figure 3-10. Metric unit abbreviations.

Metric-to-Metric Conversions
10 mm = 1 cm
10 cm = 1 dm
10 dm = 1 m
10 m = 1 dam
10 dam = 1 hm
10 hm = 1 km
Metric-to-U.S. Customary Equivalents
1 mm = 0.03937"
1 cm = 0.3937"
1 m = 39.37"
1 km = 0.625 mi.
U.S. Customary-to-Metric Equivalents
1 mi. = 1.6093 km = 1,609.3 m
1 yard (yd.) = 0.9144 m
1' = 0.3048 m = 304.8 mm
1" = 0.0254 m = 25.4 mm

Figure 3-12. Metric-to-metric conversions, common metric-to-U.S. customary equivalents, and common U.S. customary-to-metric equivalents.

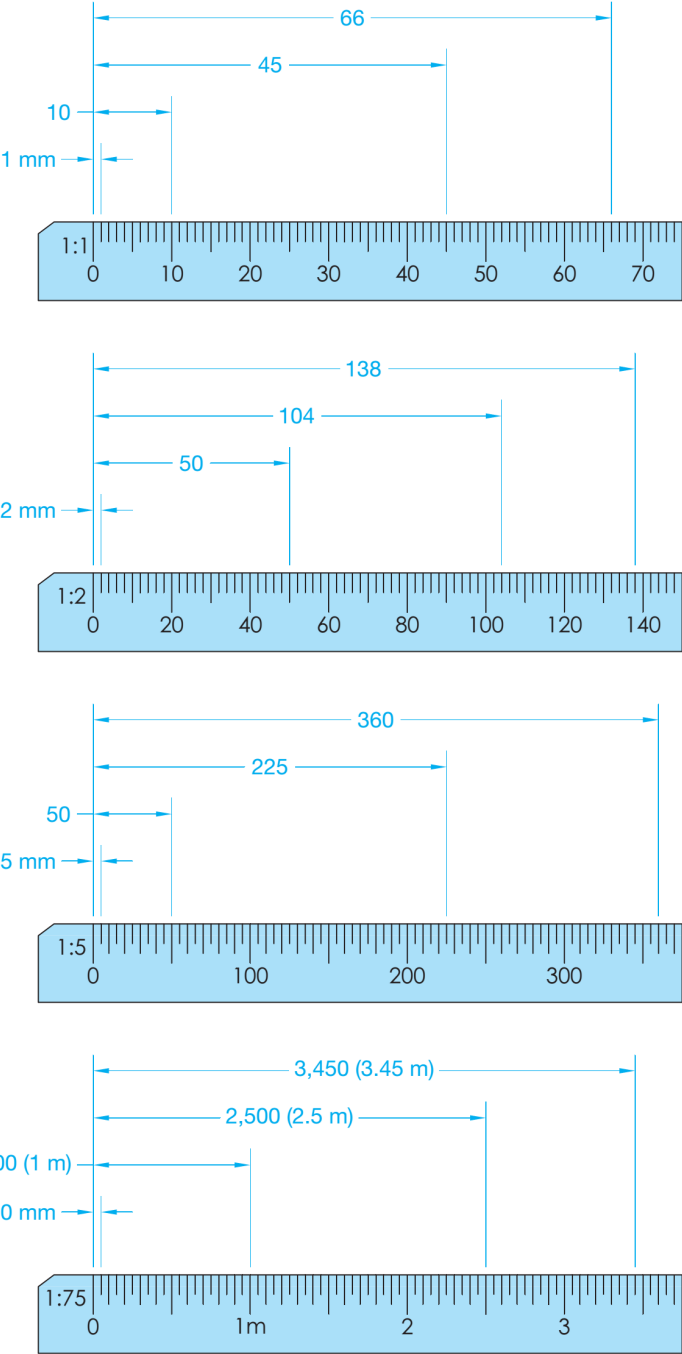


Figure 3-11. Examples of margins and scales on a metric scale.

For example, $6.5'' \times 25.4 = 165.1$ mm. Use the following formula to convert millimeters to inches:

$$\text{mm} \div 25.4 = \text{inches}$$

For example, $50 \text{ mm} \div 25.4 = 1.97''$

Map Scale	U.S. Customary	Metric
1:10,000	0.158 mi.	0.10 km
1:25,000	0.395 mi.	0.25 km
1:50,000	0.789 mi.	0.5 km
1:75,000	1.18 mi.	0.75 km
1:100,000	1.58 mi.	1 km
1:250,000	3.95 mi.	2.5 km
1:500,000	7.89 mi.	5 km
1:1,000,000	15.78 mi.	10 km

Figure 3–13. Common map scales and their U.S. customary and metric equivalents.

Note: When placing metric dimensions on a drawing, the metric abbreviation is usually omitted. A general note specifying METRIC, or UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN MILLIMETERS is placed on the drawing.

CADD Scales

CADD software provides an infinite drawing area on which objects are drawn actual size, or full scale, also known as 1:1. Drawing at full scale means that if, for example, a property line measures 150' long, you draw the line 150' long. Even if the final drawing is plotted on a 36" × 24" (architectural D) size sheet of paper, objects are still drawn full size in CADD. Use view tools, such as zooming to navigate the drawing area and adjust the displayed size of objects on-screen. **Zoom** allows you to zoom in to make objects appear larger and zoom out to make objects appear smaller without affecting the actual size of the objects. Scale the objects to fit properly on a sheet, according to a specific drawing scale. Plan your work carefully according to the correct drawing scale. The scale you select is based on a variety of factors such as the size of the area represented in the drawing, the amount of information shown, and the desired sheet size. Figure 3–14 lists standard recommended inch and metric scales for a variety of civil engineering drawings.

When you scale a drawing, you increase or decrease the displayed size of objects. AutoCAD, for example, uses the model space and paper space system for this process. **Model space** is the environment in which you create drawings and designs at full scale. **Paper space**, or **layout**, is the environment in which you prepare the final drawing for plotting to scale. The first step to make an AutoCAD drawing is to create a model in model space. A **model** is a 2-D or 3-D design composed of objects created at full scale. Once you complete a model, use a layout in paper space to prepare the final drawing for plotting. A layout represents the sheet of paper used to lay out and plot a drawing. A major element of the layout system is the floating viewport. A **floating viewport** is a viewport added to a layout in paper space to display objects drawn in model space. Floating viewports in a paper space layout offer the ability to prepare scaled drawings

Drawing Type	Scale	
	Inch	Metric
Site plans	1" = 10'	1:100
	1" = 20'	1:200
	1" = 30'	1:400
	1" = 40'	1:500
	1" = 50'	1:600
	1" = 60'	1:700
	1" = 100'	1:1,000
	1" = 200'	1:2,000
	1" = 400'	1:5,000
	1" = 500'	1:6,000
	1" = 1,000'	1:10,000
	1" = 2,000'	1:20,000
Profiles, horizontal scale	1" = 50'	1:600
	1" = 100'	1:1,000
Profiles, vertical scale	1" = 50'	1:600
	1" = 100'	1:1,000
Roadway layout	1" = 50'	1:600
	1" = 100'	1:1,000
Cut and fill	1" = 50'	1:600
	1" = 100'	1:1,000
Details	1/4" = 1'-0"	1:50
	1/2" = 1'-0"	1:20
	3/4" = 1'-0"	1:10
	1" = 1'-0"	1:10
	1 1/2" = 1'-0"	1:5
	3" = 1'-0"	1:5

Figure 3-14. Standard recommended inch and metric scales for a variety of civil engineering drawings.

without increasing or decreasing the actual size of drawing views or sheet content. Figure 3-15 shows the AutoCAD model space and paper space system used to scale a site plan.

Scale Factor

Scale factor is the reciprocal of the drawing scale, and is used in the proper scaling of various objects such as text, dimensions, and graphic patterns. These items should be the same size on a plotted sheet, regardless of the displayed size, or scale, of the rest of the drawing. Most CADD software automates the process of scaling a drawing, allowing you to focus on choosing a scale rather than calculating the scale factor. However, scale factor is a general concept with which you should be familiar, and it remains an important consideration when working with some CADD applications.

Traditional manual scaling of annotations, graphic patterns, and other objects requires determining the scale factor of the drawing scale and then multiplying the scale factor by the plotted size of the

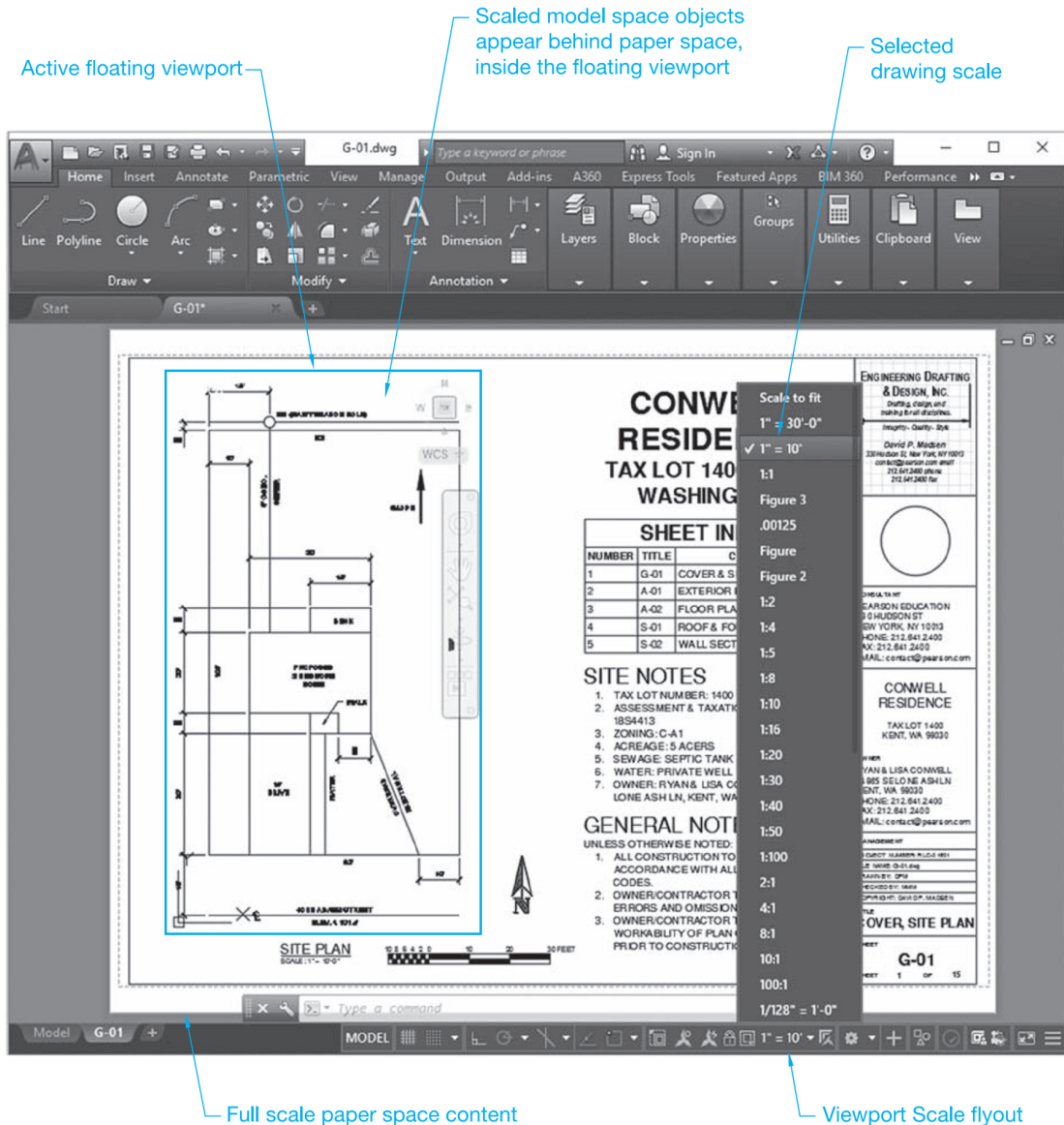


Figure 3-15. The AutoCAD model space and paper space system used to scale a site plan.

objects. Text is a convenient object to describe the application of scale factor. For example, to plot text that is 1/8" high on a drawing plotted at a scale of 1" = 50', multiply the scale factor by 1/8". The scale factor is the reciprocal of the drawing scale. A 1" = 50' scale drawing has a scale factor of 600 (50' ÷ 1" = 600). Multiply the scale factor of 600 by the text height of 1/8" to find the 75" scaled text height. The proper height of 1/8" text in an environment such as model space at a 1" = 50' scale is 75". Figure 3-16 lists common civil drawing scales and the corresponding scale factor. The figure also includes the dimensions of virtual drawing areas, or **limits**, associated with ANSI sheet sizes.

Drawing Scale	Scale Factor	Sheet Size	Limits
1" = 10'	120	A (11" × 8 1/2")	110' × 83'
		B (17" × 11")	170' × 110'
		C (22" × 17")	220' × 170'
		D (34" × 22")	340' × 220'
		E (44" × 34")	440' × 340'
1" = 20'	240	A (11" × 8 1/2")	220' × 170'
		B (17" × 11")	340' × 220'
		C (22" × 17")	440' × 340'
		D (34" × 22")	680' × 440'
		E (44" × 34")	880' × 680'
1" = 30'	360	A (11" × 8 1/2")	330' × 255'
		B (17" × 11")	510' × 330'
		C (22" × 17")	660' × 510'
		D (34" × 22")	1,020' × 660'
		E (44" × 34")	1,320' × 1,020'
1" = 40'	480	A (11" × 8 1/2")	440' × 340'
		B (17" × 11")	680' × 440'
		C (22" × 17")	880' × 680'
		D (34" × 22")	1,360' × 880'
		E (44" × 34")	1,760' × 1,360'
1" = 50'	600	A (11" × 8 1/2")	500' × 425'
		B (17" × 11")	850' × 550'
		C (22" × 17")	1,100' × 850'
		D (34" × 22")	1,700' × 1,100'
		E (44" × 34")	2,200' × 1,700'
1" = 60'	720	A (11" × 8 1/2")	660' × 510'
		B (17" × 11")	1,020' × 660'
		C (22" × 17")	1,320' × 1,020'
		D (34" × 22")	2,040' × 1,320'
		E (44" × 34")	2,640' × 2,040'

Figure 3-16. Common civil drawing scales and the corresponding scale factor. Multiply the dimension of a sheet by the scale factor to determine the drawing limits.

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Fill in the blanks with the responses necessary to complete each statement.

- 3-1** _____ is the ratio of measuring units expressing a proportional relationship between a drawing and the full-size items the drawing represents.
- 3-2** The proportion between the length of a line on a map and the corresponding length on the Earth's surface is called the _____.
- 3-3** A symbol, located in the field, legend, or margin of a sheet, with a system of ordered marks at fixed intervals used for measurement is called a _____.
- 3-4** A _____ is a type of scale only to be used as a rough estimate and is not meant to be accurate.
- 3-5** An _____ is a decimal U.S. customary (inch) scale calibrated in multiples of 10.

Part 2

Make the following conversions. Show your calculations.

- 3-6** Convert a 1:100,000 RF to a graphic scale.
- 3-7** Convert a 1:2,000 RF to a graphic scale.
- 3-8** If the number of inches between 1° of latitude on a map is measured to be 4.75", what is the RF of the map?
- 3-9** Convert a verbal scale of $1" = 1 \text{ mi.}$ to an RF.
- 3-10** Convert a verbal scale of $1" = 100 \text{ mi.}$ to an RF.

Part 3

Use a civil engineer's scale to measure the line shown below according to the specified scale calibration.

3-11 $1'' = 10'$

3-12 $1'' = 20'$

3-13 $1'' = 30'$

3-14 $1'' = 40'$

3-15 $1'' = 50'$

3-16 $1'' = 60'$

3-17 $1'' = 2'$

3-18 $1'' = 100'$

Part 4

Answer the following questions.

3-19 List the scales found on a triangular metric engineer's scale.

3-20 Give an example of what it means to create objects at full scale with CADD.

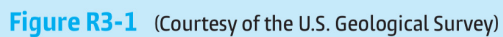
3-21 List three factors that influence selecting the drawing scale.

- 3-22** Show the formula and calculate the scale factor for a drawing scale of $1'' = 100'$.
- 3-23** Show the formula and calculate the scale factor for a drawing scale of $1'' = 30'$.
- 3-24** Calculate the actual text height to be used in a CADD system if the desired plotted text height is $1/8''$ and the drawing scale is $1'' = 20'$.
- 3-25** Given a $1'' = 10'$ drawing scale, identify the scale factor and drawing limits for an ANSI C size ($22'' \times 17''$) sheet.

Part 5

Use the graphic scale shown on the map of the State of Texas in Figure R3-1 to approximate the distance between the following locations using the most direct route.

- 3-26** Laredo to Cotulla.
- 3-27** Beaumont to Houston.
- 3-28** Dallas to the State of Louisiana.
- 3-29** Lake Meredith to Lubbock.
- 3-30** Baffin Bay to San Antonio.



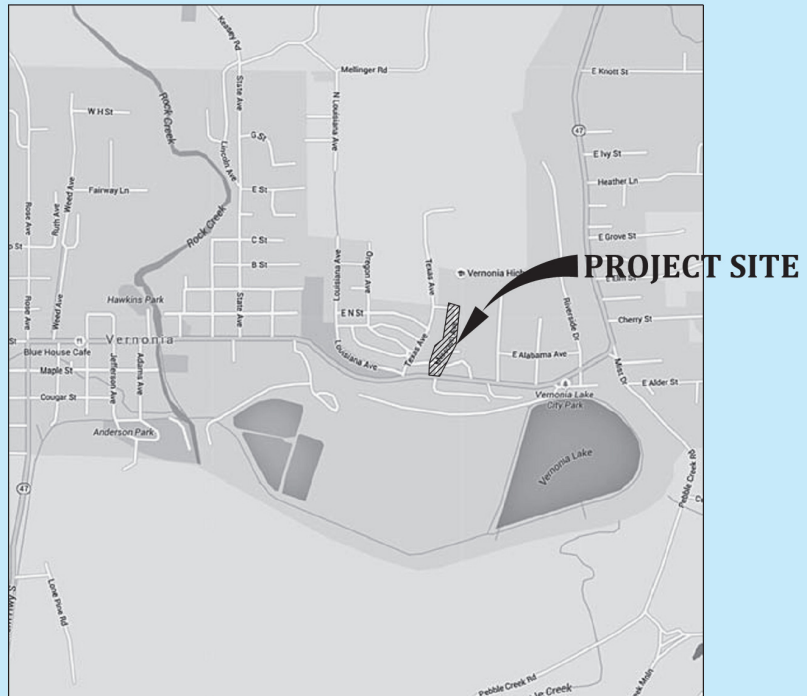
PROBLEMS

Follow the specific instructions to complete each problem.

- P3-1** List three types of civil engineering drawings and list the inch and metric scales at which each type of drawing is prepared.
- P3-2** Classify the type of drawing shown in Figure P3-2. Describe how you came to your conclusion.

Figure P3-2.

(Courtesy of KPFF Consulting Engineers)



- P3-3** Research and write a report of approximately 250 words describing the correct procedure for scaling a drawing using your CADD system. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.
- P3-4** Research and write a report of approximately 250 words describing the International System of Units (SI). Prepare a PowerPoint presentation of your research and present the slide show to your class or office.

P3-5 Convert the engineer's sketch shown in Figure P3-5 to a formal drawing. Remember, the sketch is not accurate, so you will have to lay out all bearings and distances. Use the following guidelines unless otherwise specified by your instructor:

- a. Use an ANSI C size (17" × 22") sheet.
- b. Include:
 - Title
 - Scale 1" = 10' or 1" = 20'
 - Graphic scale
 - North arrow
 - Your name and date
- c. Make a print unless otherwise specified

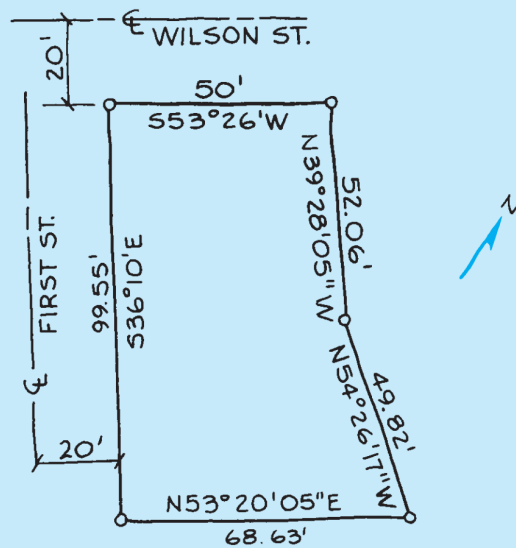


Figure P3-5.

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CHAPTER

4

Map Symbols

Learning Objectives

After completing this chapter, you will be able to:

- Define types of map symbols.
- Identify legends.
- Draw symbols.
- Explain the purpose of symbol libraries.
- Use map symbols to draw a map from given information.

Key Terms

Symbol
Culture symbols
Relief symbols
Contour line
Elevation
Water symbols
Vegetation symbols
Legend
Key
Graphic symbols legend
Graphic pattern
Block
Attributes
Insertion base point
Parameter
Symbol library
Wblock

A **symbol** is a graphic representation of a feature or an object. Maps and other civil engineering drawings typically include many different symbols. The purpose of a map dictates the required symbols. The appearance and use of symbols are based on established standards, and project and drawing requirements. Standard symbols may change slightly as necessary, and special symbols are sometimes required for a specific purpose. This chapter describes some of the symbols commonly used in civil drafting.

Types of Map Symbols

Symbols are primary elements of most maps. Symbols on a road map, for example, help you drive from one location to another. Without symbols, the map would be useless. Each type of map has symbols that are special to the intent of the map. Symbols also help keep information on a map to a minimum, so that the map remains as uncluttered as possible. Symbols are as plain and concise as possible to describe the objective. Map symbols are generally grouped as culture, relief, water, or vegetation. Special methods are often used to show symbols or to represent specific concepts on a map.

Government and private industry agencies use standard symbols on their particular maps. Examples of government agencies that produce maps are the National Oceanic and Atmospheric Administration (NOAA), U.S. Forest Service (USFS), U.S. Geological Survey (USGS), and U.S. Office of Management and Budget (OMB). Examples of private agencies that produce maps are the American Council of Engineering Companies (ACEC) and American Railway Engineering and Maintenance-of-Way Association (AREMA).

Culture Symbols

Culture symbols represent works of people. Culture symbols are usually black when a map is printed in color. Text on a map that identifies cultural representation is usually placed using vertical uppercase letters. However, variations of text style are found in CADD standards. The topographic map symbols shown in Figure 4–1 include several different cultural symbols.

Note: The NCS Uniform Drawing System, Symbols module addresses commonly used standard symbols, classifications, graphic representation, and organization in creating, understanding, and fulfilling the intent of construction documents. The standard provides a complete range of recommended symbols for all disciplines.

Relief Symbols

Relief symbols are used to show characteristics of land such as mountains and canyons. Relief may be shown by contour lines or by more descriptive means, such as color and/or technical shading methods used to create a 3-D appearance. A **contour line** is a line

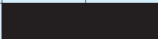
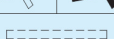
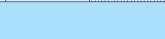
Control Data and Monuments		Buildings and Related Features	
Aerial photograph roll and frame number	3-20	Dwelling or place of employment: small; large	 
Horizontal control:		School; church	 
Third order or better, permanent mark		Barn, warehouse, etc.: small; large	 
Third order or better with elevation		House omission tint	
Checked spot elevation		Racetrack	 
Coincident with section corner		Airport	 
Unmonumented		Landing strip	
Vertical control:		Well (other than water); windmill	 
Third order or better, with tablet		Water tank: small; large	 
Third order or better, recoverable mark		Other tank: small; large	 
Bench mark at found section corner		Covered reservoir	 
Spot elevation		Gauging station	
Boundary monument:		Landmark object	
With tablet		Campground; picnic area	 
Without tablet		Cemetery: small; large	 
With number and elevation		Railroads and Related Features	
U.S. mineral or location monument		Standard gauge single track; station	 
Mines and Caves		Standard gauge multiple track	
Query or open pit mine		Abandoned track	
Gravel, sand, clay, or borrow pit		Track under construction	
Mine tunnel or cave entrance		Narrow gauge single track	
Prospect; mine shaft	 	Narrow gauge multiple track	
Mine dump	 	Railroad in street	
Tailings	 	Juxtaposition	
Marine Shoreline		Round house and turntable	 
Topographic maps:		Surface Features	
Approximate mean high water		Levee	
Indefinite or unsurveyed		Sand or mud area, dunes, or shifting sand	
Topographic-bathymetric maps:		Intricate surface area	
Mean high water		Gravel beach or glacial moraine	
Apparent (edge of vegetation)		Tailings pond	
Bathymetric Features		Transmission Lines and Pipelines	
Exposed at mean low tide or sounding datum		Power transmission line: pole; tower	 
Channel		Telephone or telegraph line	  Telephone
Offshore oil or gas: well; platform	 	Above ground oil or gas pipeline	
Sunken rock		Underground oil or gas pipeline	 Pipeline

Figure 4-1. Standard topographic map symbols.
(Based on U.S. Geological Survey symbols)

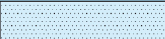
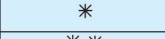
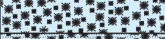
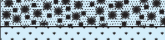
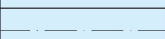
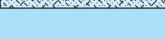
Coastal Features		Land Survey System	
Foreshore flat		U.S. Public Land Survey System	
Rock or coral reef		Township or range line; location doubtful	
Rock bare or awash		Section line; location doubtful	
Group of rocks bare or awash		Found section corner; found closing corner	
Exposed wreck		Witness corner; meander corner	
Depth curve; sounding		Other land surveys:	
Breakwater, pier, jetty, or wharf		Township or range line	
Seawall		Section line	
Glaciers and Permanent Snowfields		Land grant or mining claim; monument	
Contours and limits		Fence line	
Form lines		Contours	
Submerged Areas and Bogs		Topographic:	
Marsh or swamp		Intermediate	
Wooded marsh or swamp		Index	
Submerged wooded marsh or swamp		Supplementary	
Rice field		Depression	
Land subject to inundation		Cut; fill	
Boundaries		Bathymetric:	
National		Intermediate	
State or territorial		Index	
County or equivalent		Primary	
Civil township or equivalent		Index primary	
Incorporated city or equivalent		Supplementary	
Park, reservation, or monument		Roads and Related Features	
Small park		Light duty road	
Vegetation		Unimproved road	
Woods		Trail	
Scrub		Dual highway	
Orchard		Dual highway with median strip	
Vineyard		Road under construction	
Mangrove		Underpass; overpass	
Roads and Related Features		Bridge	
Primary highway		Drawbridge	
Secondary highway or medium duty road		Tunnel	

Figure 4-1. (Continued)

Rivers, Lakes, and Canals	
Intermittent stream	
Intermittent river	
Disappearing stream	
Perennial stream	
Perennial river	
Small falls; small rapids	
Large falls; large rapids	
Masonry dam	
Dam with lock	
Dam carrying road	
Intermittent lake or pond	
Dry lake	
Narrow wash	
Wide wash	
Canal, flume, or aqueduct with lock	
Elevated aqueduct, flume, or conduit	
Aqueduct tunnel	
Water well; spring or seep	

Figure 4-1. (Continued)

that connects points of equal elevation. **Elevation** is the height of a geographic location above or below a theoretically exact reference point, axis, or plane. Contour lines are usually thin lines, with every fifth line drawn thicker and labeled with the elevation. Contour lines and other relief symbols are usually brown when a map is printed in color. Text on a map associated with relief is usually added using vertical uppercase letters. Figure 4-1 includes examples of relief symbols. Chapter 8 explains contour lines in detail. Figure 4-2 shows additional examples of relief symbols, including special graphic techniques for drawing relief.

Water Symbols

Water symbols represent water features such as lakes, rivers, streams, and intermittent waters. Water symbols are usually blue when a map is printed in color. A continuous flowing stream is usually drawn using a solid line, while an intermittent stream often appears as a line consisting of two short dashes or dots alternating with one longer dash. A unique aspect of water symbols is that they are often labeled on a map using inclined uppercase letters, such as *MISSISSIPPI RIVER*. Figure 4-1 includes examples of water symbols. Figure 4-3 shows examples of special graphic techniques for drawing a representation of water features with rapids and whirlpools.

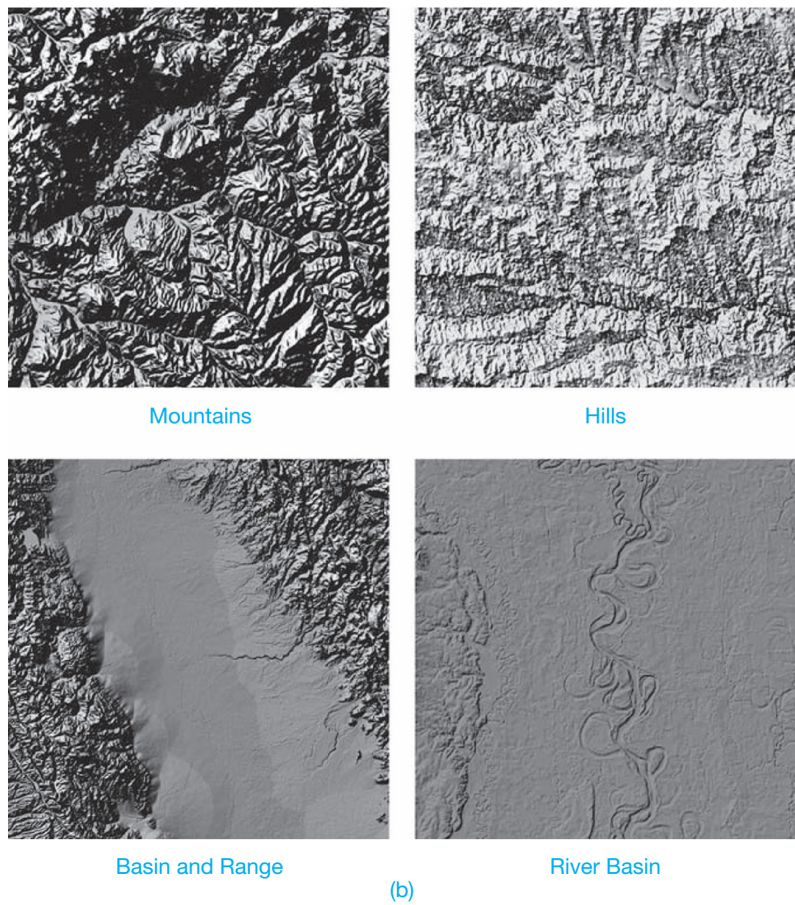
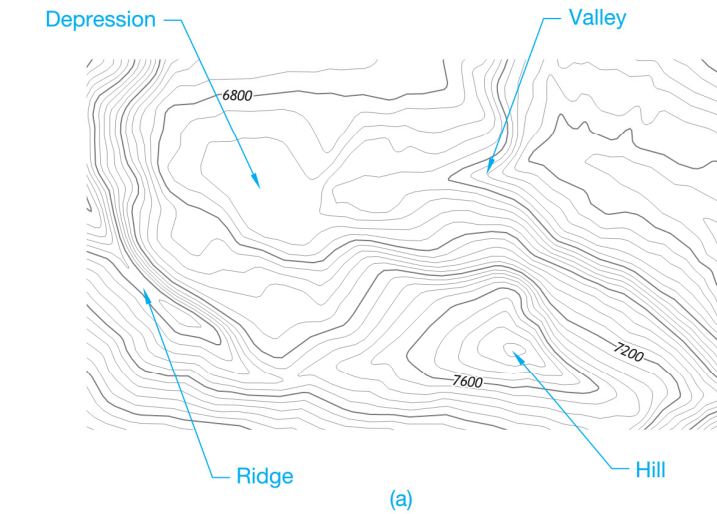


Figure 4-2. (a) A portion of a topographic map with common relief symbols. (b) Special graphic techniques for drawing common relief features.

(Topographic map courtesy of the U.S. Geological Survey)

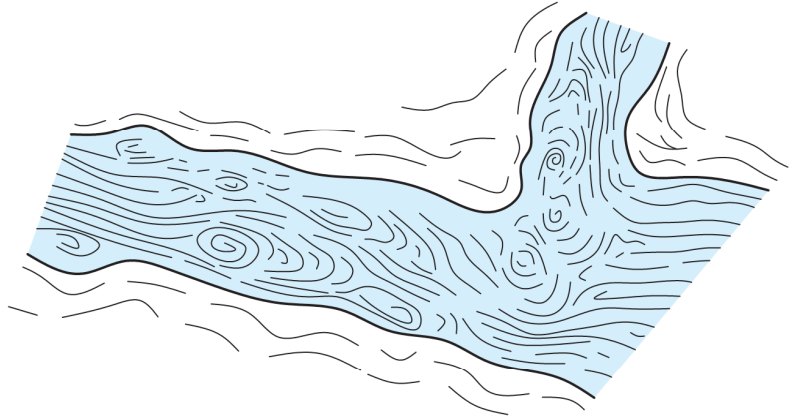


Figure 4–3. Representation of water features with rapids and whirlpools.

Vegetation Symbols

Vegetation symbols represent forests, orchards, croplands, and other types of plant life. Vegetation symbols are usually green when a map is printed in color. Some maps classify vegetation planted by people, such as a field of corn, as culture. Maps can show specific crops grown in an area or information about how land is being used. Figure 4–1 includes examples of vegetation symbols. Figure 4–4 shows additional examples of vegetation symbols.

Legends

A map **legend**, or **key**, explains the symbols, colors, and labels that makeup the map or drawing data. A legend is necessary in order to understand the information presented on a map. The legend shown in Figure 4–5, for example, keys population, transportation, and physical land and water feature symbols to the map. A legend is a common element found on many different types of civil engineering drawings. Figure 4–6 shows an example of a notes legend used to group delta, or key, notes. A legend that identifies symbols found on a drawing is sometimes referred to as a **graphic symbols legend** (see Figure 4–7).

A drawing may include one or more legends, typically located on one side of the sheet. Some legends are large enough to occupy an entire sheet. A legend is primarily for interpretation of drawing information but can also act as a drafting tool. For example, copy and paste symbols from the legend to a drawing view, or match the properties assigned to a line in the legend to objects in a drawing view.

Creating and Using Symbols

Several CADD symbol techniques are available, depending on the specific software. The symbols displayed throughout this chapter can be created using a variety of commands and tools. Symbols are drawn

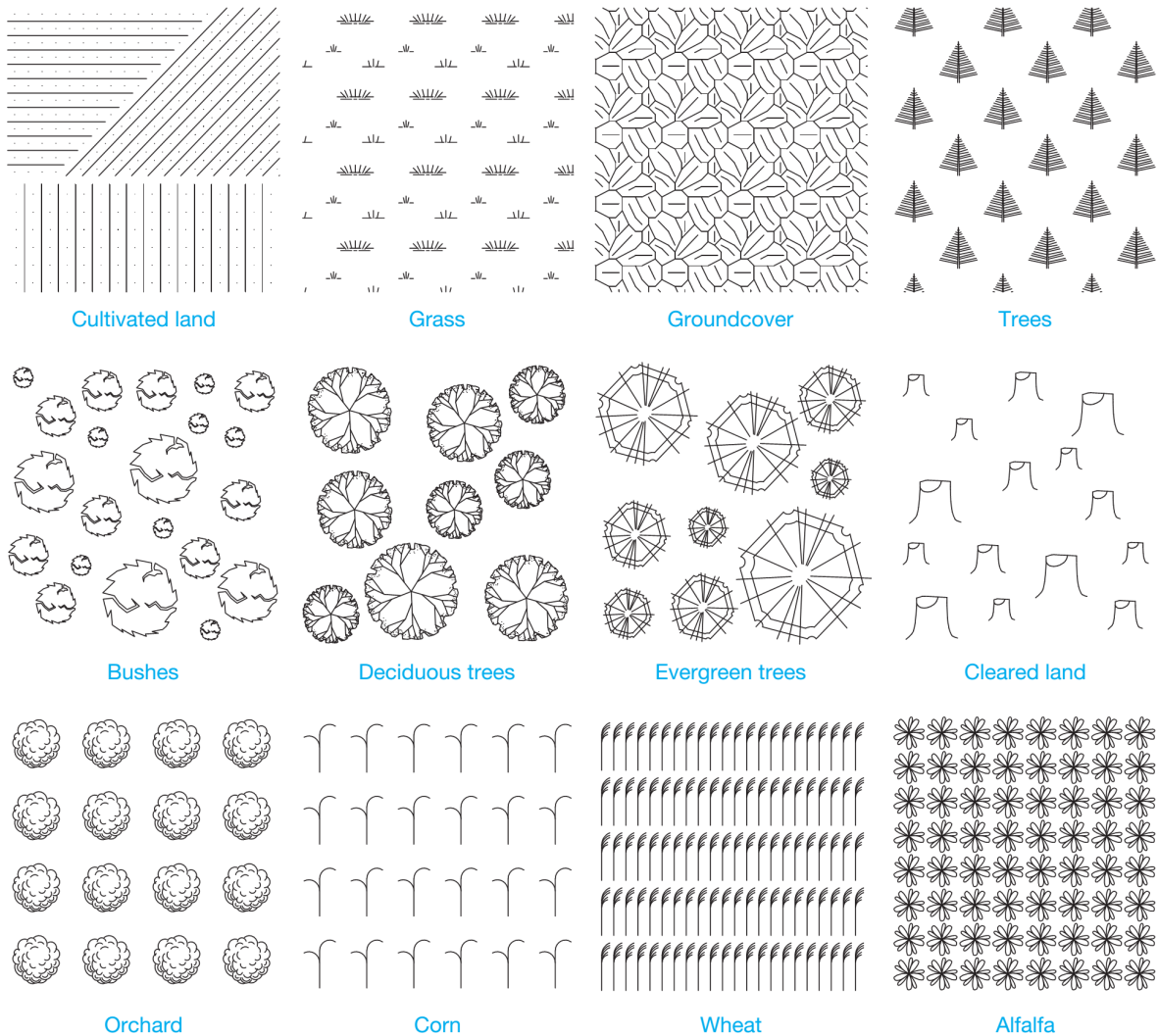


Figure 4-4. Examples of vegetation symbols.

with various object commands, and can be arranged and patterned as needed. Many symbols, such as the boundary and contour line symbols shown in Figure 4-1, can be drawn using standard object commands and a specific line type and weight. A custom line type is often used to draw objects such as utility lines. For example, create a dashed line that automatically places the letter T, representing telephone, along the line to add a telephone line symbol to a map.

CADD software provides methods for sizing, moving, rotating, copying, and mirroring objects. The area covered by bushes shown in Figure 4-4, for example, was created by copying and resizing a symbol of a bush. Tools, such as AutoCAD's ARRAY command, help you draw multiple copies of an object arranged in a pattern. The portion of an orchard shown in Figure 4-4, for example, was generated by the rectangular array of a tree symbol. The municipal airport symbol shown in Figure 4-8 was completed using a circular, or polar, array of a filled circle.

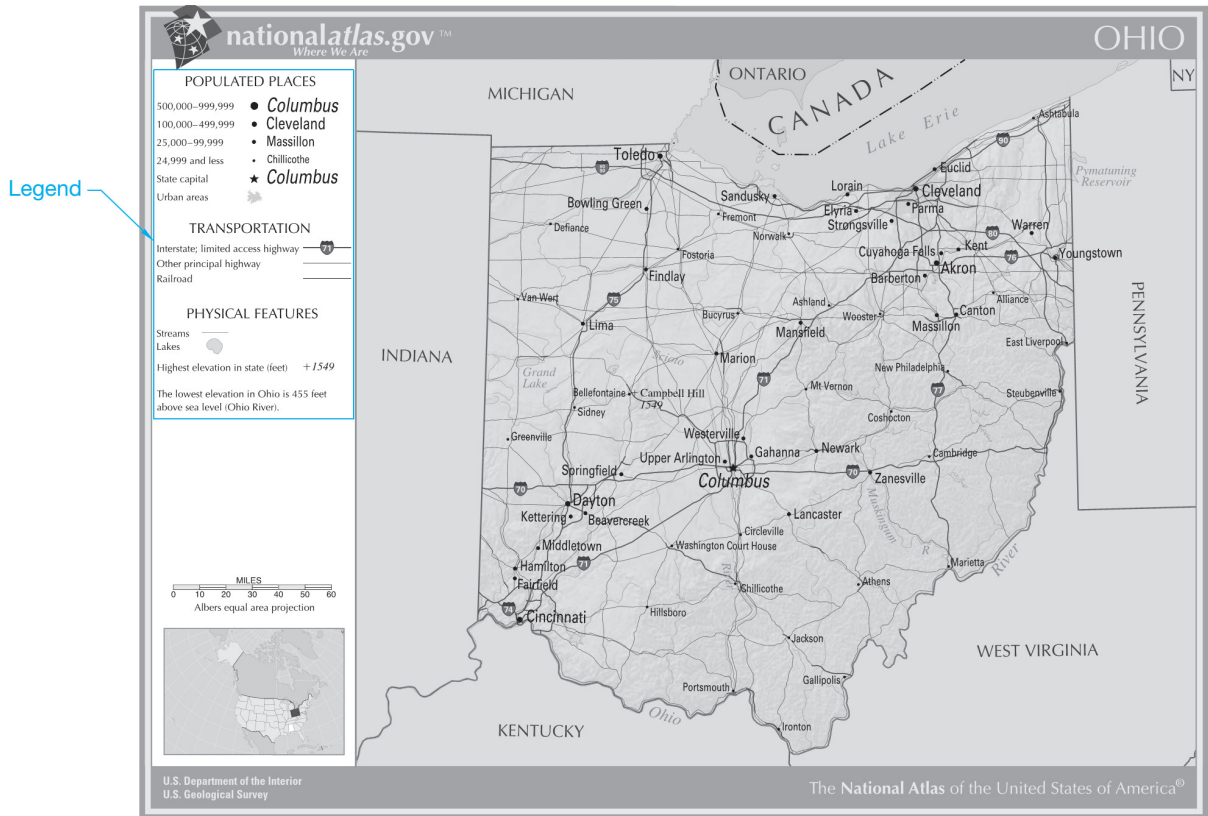


Figure 4–5. A general reference map of the State of Ohio. This map includes a legend that keys population, transportation, and physical land and water feature symbols to the map.
(Courtesy of the U.S. Geological Survey)

Graphic Patterns

A common symbol technique involves the use of graphic patterns. A **graphic pattern** is a patterned arrangement of objects or symbols. CADD graphic pattern tools, such as AutoCAD's HATCH command, automate the process of drawing graphic patterns, such as the arrangement of lines used to symbolize a city or town shown in Figure 4–8. Figure 4–9 shows an example of a detail drawing on which areas of symbols have been placed using a graphic pattern tool. In this example, sidewalks and other concrete structures are represented using diagonal lines or a concrete representation, soil is shown using crossing and diagonal lines, rock aggregate is shown using a gravel representation, and grassy areas are represented by grass symbols. Each of these areas, or pattern boundaries, was created as a single object using a graphic pattern tool.

Symbol Tools

As you become familiar with CADD, you will discover many options that enhance your ability to quickly and accurately place symbols. Most CADD systems include specific tools and options for defining,

○ STREET AND STORM CONSTRUCTION NOTES

- ① CONSTRUCT SIDEWALK RAMP PER DETAIL ON SHEET C5.5. RAMP AND SIDEWALK ALONG CURB RETURN TO BE CONSTRUCTED WITH PUBLIC STREET IMPROVEMENTS.
- ② CONSTRUCT RESIDENTIAL DRIVEWAY PER DETAIL ON SHEET C5.4. DRIVEWAY APRONS TO BE CONSTRUCTED WITH HOME CONSTRUCTION.
- ③ CONNECT TO EXISTING STORM MANHOLE.
- ④ CONSTRUCT SIDEWALK WITH STREET IMPROVEMENTS.
- ⑤ INSTALL CENTERLINE SURVEY MONUMENT PER DETAIL 3010(B) ON SHEET C5.4.

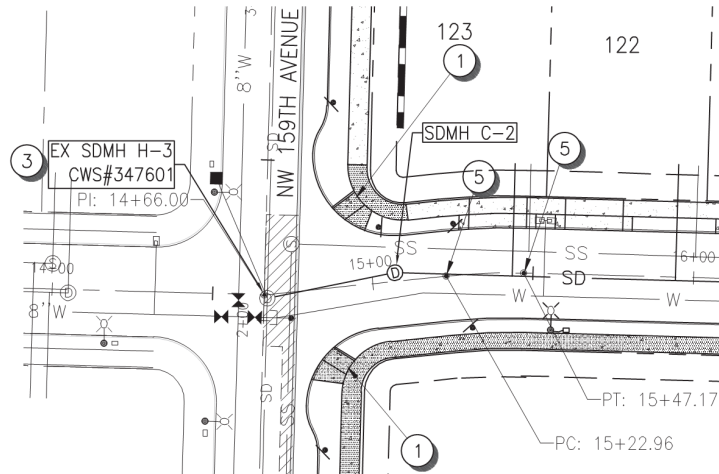


Figure 4-6. A portion of a street and storm drain plan with key notes in a legend used to link specific notes to features in the drawing.
(Courtesy of Otak, Inc.)

saving, and inserting symbols. An example is AutoCAD's block tools. A **block** is an AutoCAD symbol object saved and stored in a drawing file for future use. A CADD symbol can consist of any object or group of objects, or can be an entire drawing. Review each drawing and project to identify items you can use more than once. Draw the objects once and then save them as a symbol for multiple use.

Symbols are created like other items in a drawing with lines, objects, text, attributes, and other annotations. **Attributes** are text-based data assigned to a specific object. Attributes enhance blocks that require text or numerical information. For example, the cutting-plane line and view title symbols shown in Figure 4-10 include data that links the plan view to the cross section in a set of drawings. Adding attributes to the cutting-plane line and view title symbols allows you to specify unique values for each symbol, without creating new symbol definitions for each cutting-plane line and view title. You can also extract attribute data to automate drawing requirements such as preparing schedules and bills of materials.

When you finish drawing the objects that comprise the symbol, determine the best location for the insertion base point. The **insertion base point** is the point on a symbol that defines where the symbol is positioned during insertion. Figure 4-11 shows examples of symbols

LEGEND - UTILITY SYMBOLS

EXISTING		NEW	
	EXISTING MANHOLE		MANHOLE
	CLEANOUT		CLEANOUT
	CATCH BASIN		CATCH BASIN
	POLLUTION CONTROL MANHOLE		POLLUTION CONTROL MANHOLE
	DRYWELL		DRYWELL
	WATER METER		WATER METER
	FIRE HYDRANT		FIRE HYDRANT
	GATE VALVE		GATE VALVE
	BUTTERFLY VALVE		BUTTERFLY VALVE
	REDUCER		REDUCER
	BLOWOFF		BLOWOFF
	RESERVOIR		RESERVOIR
	PUMP STATION		PUMP STATION
	METER VAULT		METER VAULT
	PRESSURE REDUCING STATION		PRESSURE REDUCING STATION
	PRESSURE SENSOR		PRESSURE SENSOR
	PRESSURE REDUCER		PRESSURE REDUCER
	AIR RELIEF VALVE (OFFSET)		AIR RELIEF VALVE (OFFSET)
	AIR RELIEF VALVE (ON LINE)		AIR RELIEF VALVE (ON LINE)
	NORMALLY CLOSED VALVE		NORMALLY CLOSED VALVE
	GAS METER		GAS METER
	GAS VALVE		GAS VALVE

Figure 4-7. A legend that shows existing and new utility symbols.
(Courtesy of PACE Engineers, Inc.)

and a possible insertion base point for each. Though you can move and adjust symbols once inserted, defining an effective insertion base point will save time and assist in accurately placing the symbol. Give each symbol a descriptive name and record a copy of the symbol, the symbol name, and the insertion base point for future reference.

A symbol can be saved alone or grouped with other symbols in a file. Depending on the CADD program, a symbol inserted into a drawing functions as a single object and can be adjusted much like other objects in the drawing. When possible, make a symbol one unit wide by one unit high. This allows you to insert the symbol in relationship to the drawing units. This also gives you the flexibility to scale the symbol when inserting to fit the requirements of a drawing. Figure 4-12 shows the typical basic steps required to create a symbol for future use. Some CADD systems allow you to assign parameters and actions to objects within the symbol to create

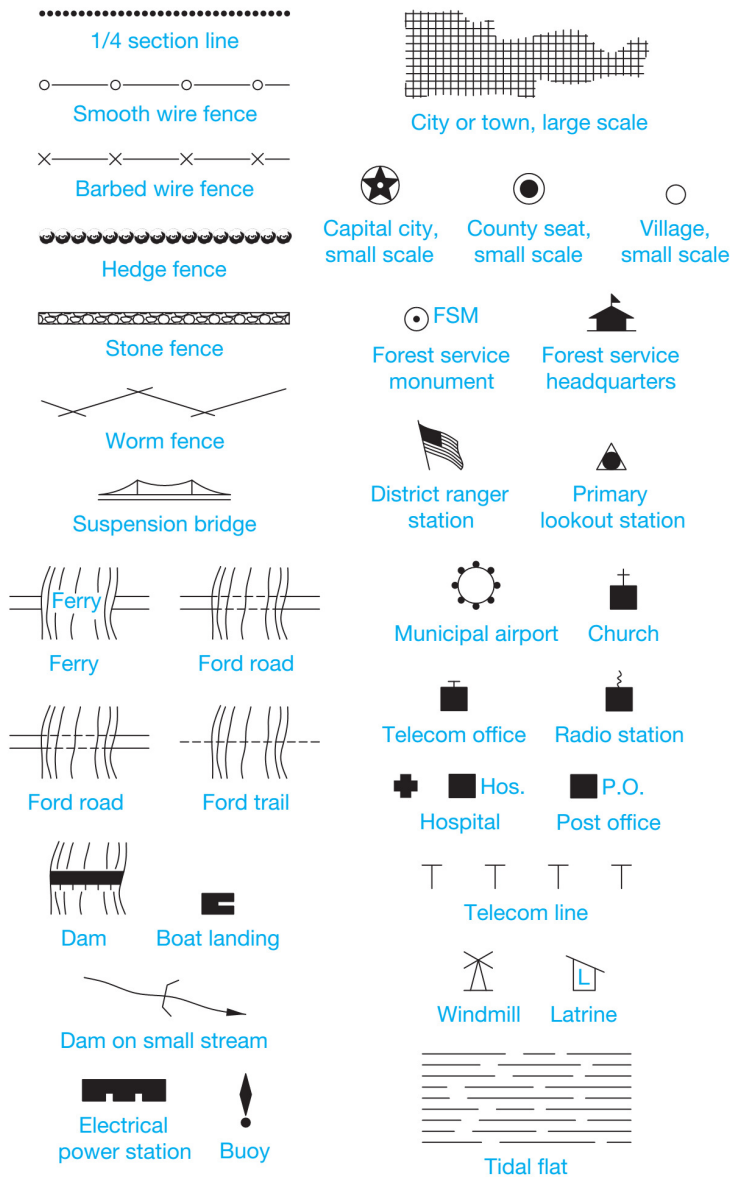


Figure 4-8. Additional map symbols.

a dynamic symbol. A **parameter** is a geometric characteristic and dimension that controls the size, shape, and position of geometry. A dynamic block can be adjusted to create a unique variation of the symbol without redrawing the symbol, and without affecting other instances of the same symbol.

Symbol Libraries

Most engineering companies and agencies have an extensive library of saved symbols and drawings. A **symbol library** is a directory of

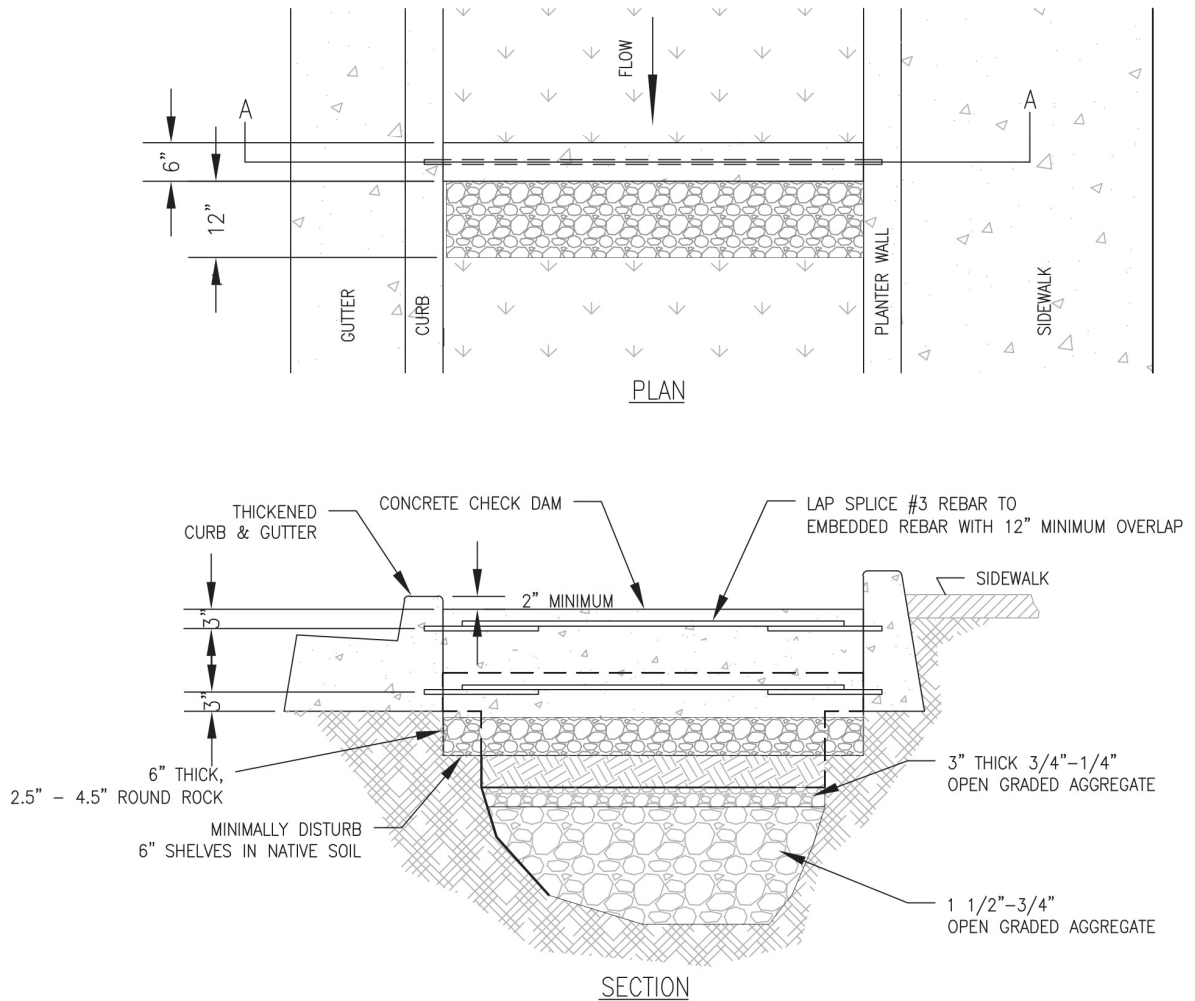


Figure 4-9. A concrete check dam detail with graphic patterns used to symbolize concrete, soil, rock, and grass.

(Courtesy of Otak, Inc.)

symbols that can be accessed for use on a drawing. Symbol libraries can contain hundreds or thousands of symbols. A project may use many standard symbols and details, some requiring minor changes in dimensions, materials, and construction methods. It is important for you to be aware of the kinds of symbols and details that are archived in drawing and symbol libraries.

Store frequently used symbols in symbol libraries to increase productivity. Continue to add new symbols to libraries to increase the number of symbols available for reuse. There are two general methods to create a symbol library. One option is to save multiple symbols in a single drawing file (see Figure 4-13). The other technique is to save each symbol to a separate file. When using AutoCAD, for example, a block definition saved as a separate drawing file is

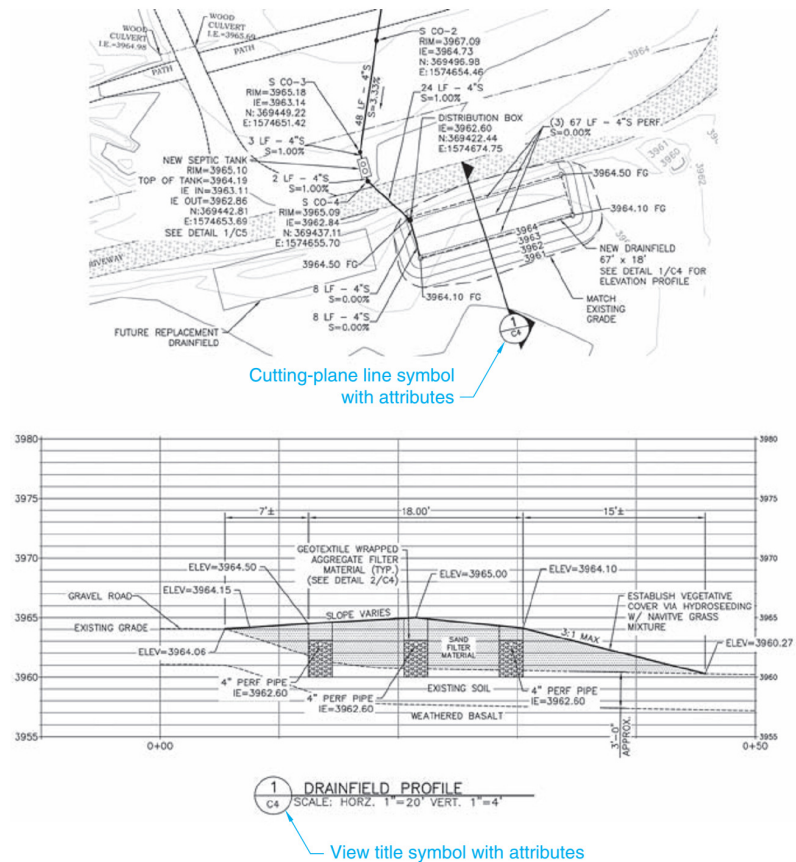


Figure 4-10. The cutting-plane line symbol shown on a plan view and the view title symbol shown with the section view include attributes that link the plan view to the cross section in a set of drawings.
(Courtesy of KPFF Consulting Engineers)

called a **wblock**. Consider the following guidelines when developing a symbol library:

- Follow appropriate drafting standards.
- Identify each symbol with a descriptive name and insertion base point location.
- When saving multiple symbols in a drawing file, save one group of symbols per drawing file and use folders to organize files.
- When creating individual symbols as separate files, give each file a meaningful name and use folders to organize files.
- Provide all users with a hard copy of the symbol library showing each symbol, insertion points, storage locations, and any other necessary information.
- If a network is not in use, place symbol library files on each workstation in the classroom or office.
- Keep backup copies of all files in a secure location.
- When you revise symbols, update all files containing the edited symbols as appropriate.
- Inform all users of any changes to saved symbols.

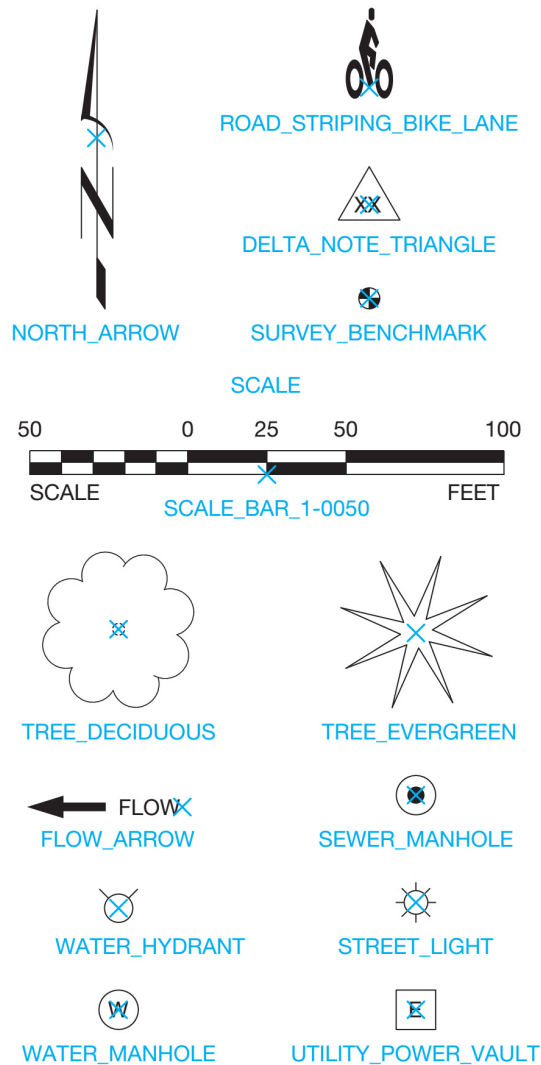


Figure 4-11. Common civil drafting symbols. The colored $\times$ identifies the insertion base point.

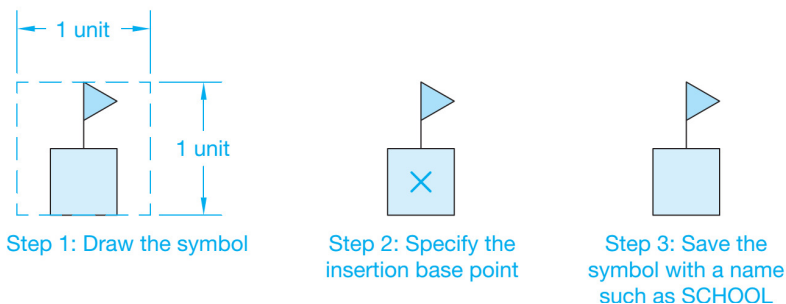


Figure 4-12. The typical basic steps required to create the symbol of a school for use on a map.

UTILITY SYMBOLS

GENERAL

-  UTIL_FIRE_HYDRANT
-  UTIL_MANHOLE
-  UTIL_UTIL_POLE
-  UTIL_FUEL_STOR_TANK

WATER

-  UTIL_WTR_HANDHOLE
-  UTIL_WTR_MANHOLE
-  UTIL_WTR_METER
-  UTIL_WTR_METER_STA
-  UTIL_WTR_PLANT
-  UTIL_WTR_STA_PUMP
-  UTIL_WTR_STOR_TANK
-  UTIL_WTR_TANK
-  UTIL_WTR_VALVE_VAULT

SANITARY SEWER

-  UTIL_SAN_CLEANOUT
-  UTIL_SAN_MANHOLE
-  UTIL_SAN_METER
-  UTIL_SAN_PRESS_VESSEL
-  UTIL_SAN_VALVE_VAULT
-  UTIL_SEPTIC_TANK

NATURAL GAS

-  UTIL_NAT_GAS_MANHOLE

Figure 4-13. A portion of a symbol library showing multiple utility symbols saved in a single drawing.

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Define the following map symbols.

4-1 Culture

4-2 Relief

4-3 Water

4-4 Vegetation

4-5 Legend

Part 2

Sketch an example of the following symbols.

4-6 Primary highway

4-7 Light-duty road

4-8 Railroad, single track

4-9 Bridge and road

4-10 Building (dwelling)

4-11 Power transmission line

4-12 Perennial stream

4-13 Intermittent stream

4-14 Marsh

4-15 Orchard

4-16 Hill

4-17 Ridge

4-18 Depression

4-19 Valley

4-20 River

Part 3

Choose the response that best describes each statement.

- 4-21** An AutoCAD symbol object saved and stored in a drawing file for future use is called a(n):
- a. Attribute
 - b. Table
 - c. Block
 - d. Hatch

- 4-22** The AutoCAD command that helps you draw multiple copies of an object arranged in a pattern is called the:
- a. INSERT command
 - b. ARRAY command
 - c. PATTERN command
 - d. SCALE command
- 4-23** A patterned arrangement of objects or symbols is known as a(n):
- a. Offset
 - b. Graphic symbols legend
 - c. Graphic pattern
 - d. Repetitive feature
- 4-24** The insertion base point is the point on a symbol that:
- a. Allows you to extract attribute data to automate drawing requirements
 - b. Can be used to adjust the size and shape of symbol geometry
 - c. Determines the length, width, and height of the symbol
 - d. Defines where the symbol is positioned during insertion
- 4-25** A directory of symbols that can be accessed for use on a drawing is called a:
- a. Key
 - b. Symbol library
 - c. Block
 - d. Block definition

PROBLEMS

Follow the specific instructions to complete each problem.

- P4-1** Sketch and label two examples each of culture, relief, water, and vegetation symbols.
- P4-2** Classify the type of map shown in Figure P4-2. Describe how you came to your conclusion.

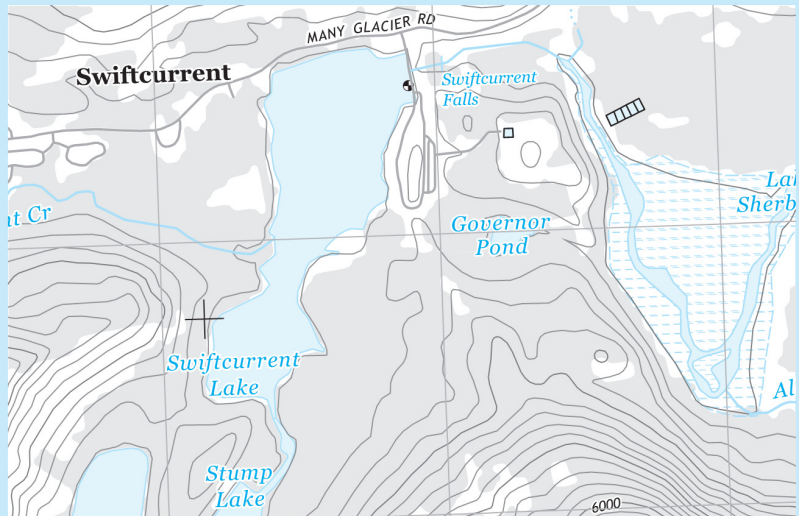


Figure P4-2.
(Courtesy of the U.S. Geological Survey)

- P4-3** Research and write a report of approximately 250 words describing the correct procedure for drawing a graphic pattern using your CADD system's graphic pattern tool. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.
- P4-4** Research and write a report of approximately 250 words describing the correct procedure for defining, saving, and inserting symbols using your CADD system's symbol tools. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.
- P4-5** Use the following instructions to sketch the map in the space provided in Figure P4-5:
- Use standard topographic symbols.
 - Use appropriate mapping colors, unless otherwise instructed.
 - North is toward the top of the page.
 - The scale is $1'' = 200'$.
 - Draw a hard-surface medium-duty road from point A to point F.
 - Beginning 975' from point A, draw a bridge over a 40' wide river.
 - The center of the river runs through points B, C, D, and E.
 - At 420' from point A along the hard-surface road, draw an improved light-duty road to point G.
 - A small creek enters the river at point C. The creek is straight and runs for 385' at a 45° angle, then turns, with a radius of 200', approximately due north.

- j. North of the medium-duty road and southwest of the river, the entire area is orchard to within 200' of the river.
- k. The area south of the medium-duty road and west of the light-duty road is a corn crop.
- l. On both sides of the small creek is a grove of deciduous trees 100' wide.
- m. All other areas are grasslands.
- n. At 200' northeast of the bridge and on the north side of the medium-duty road is a forest service headquarters.

P4-6 Use your CADD system to draw the map described in Problem P4-5. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 4-6.dwg file to use as a drawing template.

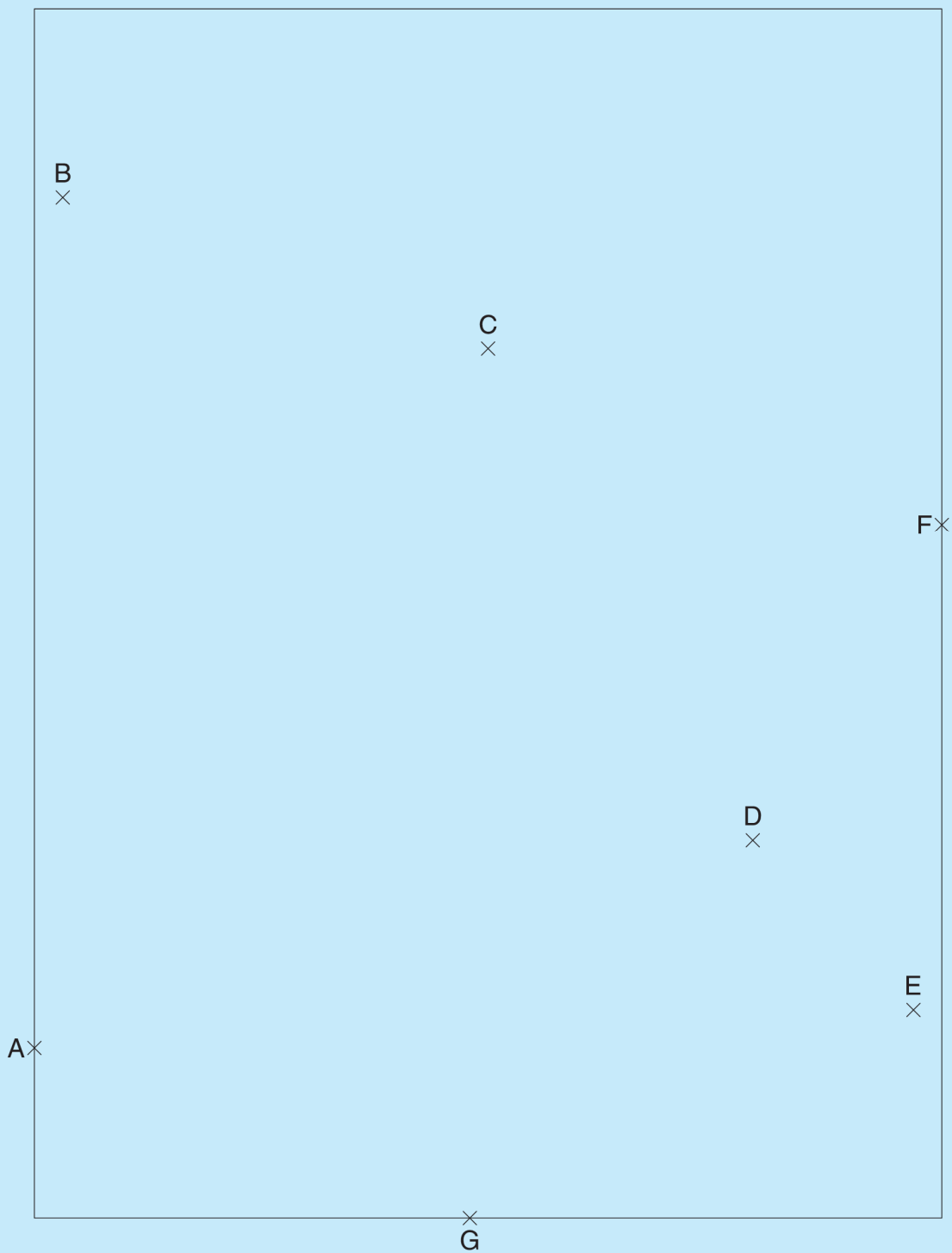


Figure P4-5.

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CHAPTER

5

Introduction to Surveying

Learning Objectives

After completing this chapter, you will be able to:

- Explain the difference between geodetic and plane surveys.
- Identify different types of surveys and the maps created by them.
- Identify conventional ground surveying equipment.
- Describe survey data collection and output.
- Describe global navigation satellite system (GNSS) technology and applications.
- Explain 3-D scanning technology and applications.
- Define remote sensing.

Key Terms

Surveying
Surveyor
Geodesy
Geodetic survey
Oblate spheroid
Triangulation
Triangulation stations
Bench mark (BM)
Plane
Plane survey
Control survey
Land survey
Boundary survey
Property survey
Cadastral survey
Topographic survey
Hydrographic survey
Hydraulic survey
Photogrammetric survey
Photogrammetry
Aerial photographs
Route survey
Construction survey
As-built survey
As-built drawing
As-built
Total station
Electronic distance meter (EDM)
Field notes
Shot
Digital terrain model (DTM)

(continued)

Key Terms (*continued*)

Triangulated irregular network (TIN)	Rover	Georeferenced image
Breakline	Aerotriangulation	Mobile ground-based laser scanning
Spot elevation	Interpolation	Mobile terrestrial laser scanning
Global navigation satellite system (GNSS)	3-D laser scanning	Mobile laser scanning (MLS)
Global Positioning System (GPS)	Light Detection and Ranging (LiDAR)	Mobile mapping
Satellite constellation	3-D laser scanner	Aerial laser scanning (ALS)
Trilateration	Point cloud	IMU
Selective availability (SA)	Stationary ground-based laser scanning	Remote sensing
Differential GPS	Static terrestrial laser scanning	Unmanned aerial vehicles (UAV)
Differential correction	High-resolution surveying	Unmanned aerial system (UAS)
Base station		Drone

Surveying is the science of measuring distances, angles, and directions of characteristics of the Earth's surface. Maps and drawings for civil engineering projects are created using information obtained from surveys. Surveying is an early phase of the civil engineering design process and often continues throughout a project. Surveying is often contracted to licensed surveyors. A **surveyor** provides a map of the job site from which civil designers and drafters develop drawings. This chapter introduces surveying and describes a variety of surveying concepts and procedures.

Geodetic Surveys

Geodesy is the science of measuring the size and shape of the Earth and the location of points on the Earth's surface. A **geodetic survey** is a survey that factors in the curvature of the Earth. Geodetic surveys are appropriate for surveying large areas, generally greater than three square mi. (five square km), because they account for the curvature of the Earth. The Earth is referred to as a sphere, but it is technically an oblate spheroid. An **oblate spheroid** is an ellipsoid that contains two centers of equal radius, rotated around the minor axis (see Figure 5-1). The diameter of the Earth measured through the poles is approximately 27 mi. (43 km) less than the diameter measured at the equator, as shown in Figure 5-1. The rotation of the Earth creates the 27 mi. bulge at the equator. The bulge causes a variation in the length of a degree of latitude near the poles. Figure 5-2 lists the approximate measurements of the Earth. Chapter 6 explains latitude and longitude.

Triangulation

Triangulation is a survey method used to establish control points with accurate horizontal and vertical positions used for reference during other surveys. **Triangulation** is the method of establishing a triangle or series of adjoining triangles as a network in order to determine the distances and locations of points based on measured interior angles

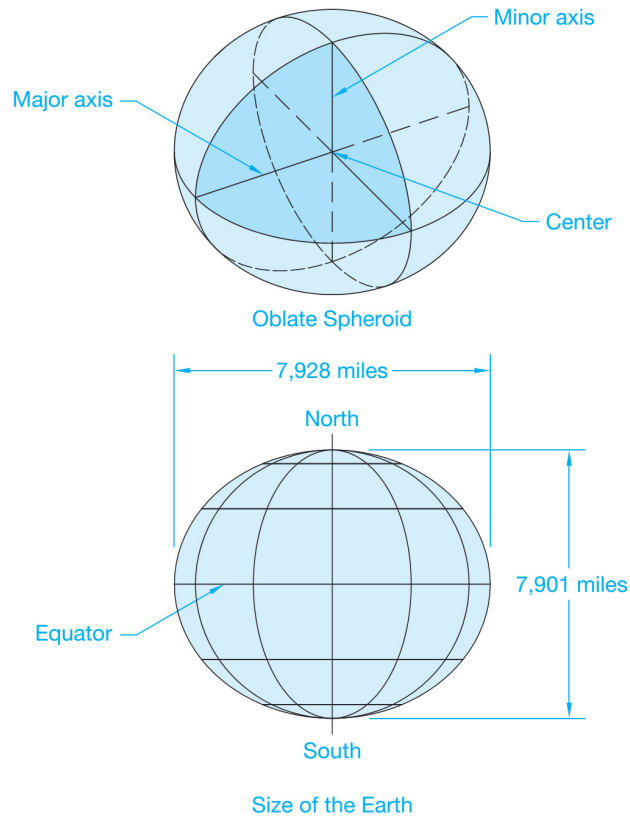


Figure 5-1. The diameter of the Earth measured through the poles is approximately 27 mi. less than the diameter measured at the equator.

and two known points (see Figure 5-3). Some sides of the intersecting triangles may be many miles long.

Triangulation provides the ability to calculate an unknown distance based on the known length and interior angles between one side of a triangle, called the baseline. Triangulation also allows you to calculate an unknown direction based on the known angle of one side of a triangle. The vertices of the triangulation triangles are known as **triangulation stations**. In a triangulation network, it is common, and desirable, to measure all three interior angles of each triangle. The locations of vertices or station points are chosen to provide a line-of-sight that enables measurement of all angles.

<i>Measurement</i>	<i>Approximate Value</i>
Equatorial diameter	7,928 mi. (12,756 km)
Equatorial circumference	24,907 mi. (10,075 km)
Length of 1° of longitude at the equator	69.186 mi.
Polar diameter	7,901 mi. (12,713 km)
Polar circumference	24,822 mi. (39,938 km)
Length of 1° of latitude	68.96 mi.

Figure 5-2. The approximate measurements of the Earth.

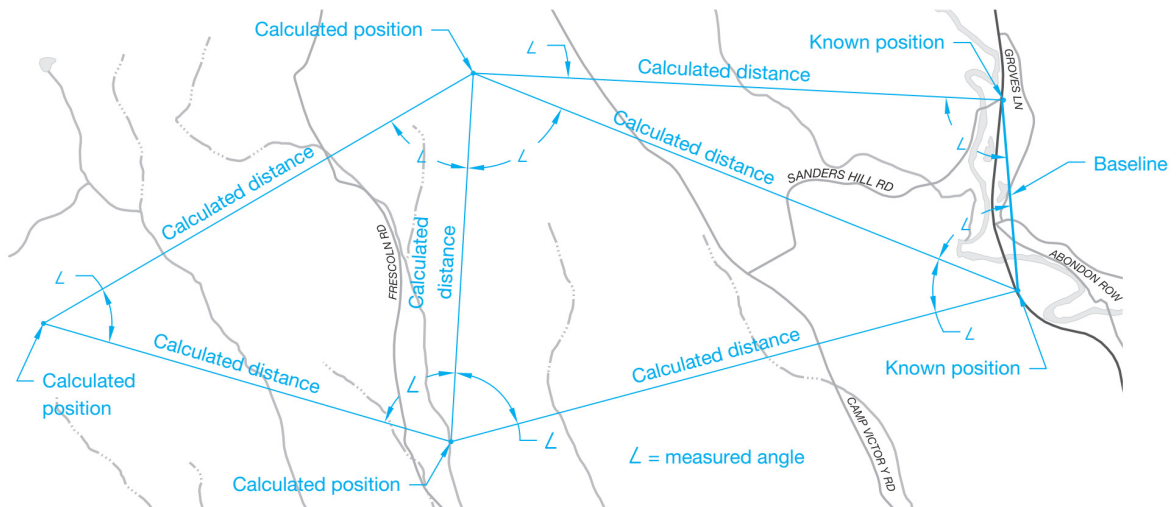


Figure 5-3. The concept of triangulation applied to map a large area.



Figure 5-4. A triangulation station survey mark set during a geodetic survey.
(Courtesy of the National Geodetic Survey)

Reference Points

Geodetic surveys are typically conducted by federal government agencies; and occasionally by state and local government agencies and private companies. The result of a geodetic survey is the placement of accurate reference points or survey marks. Survey marks are intended to be permanent and are typically a brass cap mounted in concrete or a metal cap attached to a pipe and sunken into the ground. Figure 5-4 shows a triangulation station survey mark set during a geodetic survey.

Survey marks provide accurate horizontal (latitude and longitude) and/or vertical (elevation) coordinates. A bench mark (BM) is a common example of a survey mark. A **BM** is a survey mark intended to be permanent that specifies the latitude, longitude, and elevation of a point. A BM provides precise vertical control for measuring elevations but may only specify an approximate horizontal position. Chapter 6 explains location and distance.

The National Geodetic Survey (NGS) maintains the entire set of survey marks for the United States, in the National Spatial Reference System (NSRS). The network of control markers established by geodetic surveys is used as reference for other surveys, such as those described later in this chapter. Surveyors use survey marks to confirm and complete precise and reliable surveys for any project requiring accurate geodetic data.

Plane Surveys

A **plane** is a flat surface. A **plane survey** is a survey conducted as if the Earth were flat, without factoring in the curvature of the Earth. Plane surveys are accurate for small areas, generally less than three square mi. (five square km), because the curvature of the Earth has a minimal effect over short distances. For example, the length of an

Figure 5-5. The lengths of a 36 mi. (58 km) arc and a chord connecting the arc's ends vary by only 0.66'.

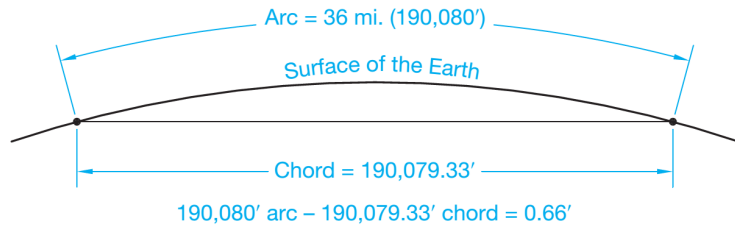
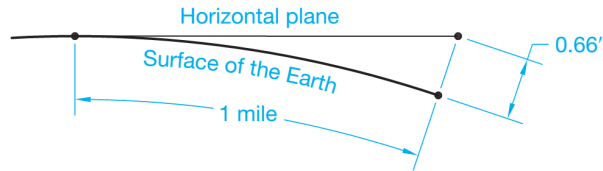


Figure 5-6. A horizontal plane is only 0.66' above the Earth's surface at the end of a 1 mi. arc.



arc along the curved surface of the Earth is only approximately 0.66' (20 cm) longer across the 36 mi. (58 km) width of a section of land than the length of a straight line, or chord, between the arc's end points (see Figure 5-5). Figure 5-6 shows an example of the offset of a plane in relation to the Earth's surface. In this case, at the end of a 1 mi. arc, a horizontal plane is only 0.66' above the Earth's surface.

Plane surveys work well for the surveying required for most civil engineering projects, as most projects cover smaller areas of ground. A benefit to plane surveys is that mathematical calculations are conducted using plane geometry and trigonometry, unlike the more complex spherical geometry and trigonometry required to solve geodetic survey calculations. Most of the drawings described in this textbook are prepared from data collected using plane surveys with control from geodetic survey reference points.

Types of Surveys

Surveys are conducted whenever there is a need to collect data about natural or human-made features. City planners rely on surveys to evaluate urban expansion and improvement projects. Foresters use surveys to inventory timber and manage timberland. Mine operators use surveys to map rock formations and estimate quantities of material to be mined. These are a few examples of the many different types of surveys related to specific requirements and projects. The following information focuses on common types of surveys associated with civil engineering and drafting. Most of the following surveys typically use plane survey practices. New surveys reference existing surveys or an organized reference grid or coordinate system.

Control Surveys

A **control survey** establishes control points with accurate horizontal and/or vertical positions. Control surveys are typically geodetic surveys used for reference during other surveys, including the ground

and aerial surveys described later in this chapter. Horizontal control points provide accurate location, latitude and longitude, and control for features such as a property lines and road centerlines. Vertical control points offer vertical distance, or elevation, reference.

Land Surveys

A **land survey**, also known as a **boundary survey**, **property survey**, or **cadastral survey** locates property corners and boundary lines. The site upon which your house or apartment, and school or office is built was surveyed using a land survey. If you own land, a map, known as a plat, of your plot of land is on file at your city, county, borough, or parish courthouse. Figure 5–7 shows a drawing of a subdivision boundary generated from data collected during a land survey.

Topographic Surveys

A **topographic survey** provides accurate location and elevation data of natural and human-made features on land. The information obtained during a topographic survey is presented on a topographic map (see Figure 5–8). You will learn more about topographic maps later in this textbook.

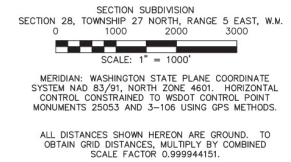
Hydrographic Surveys

A **hydrographic survey** accurately locates and measures the boundaries and characteristics of surface waters, or hydrography. Hydrographic surveys provide data about drainage; water depth; the shape of the sea floor, lake bed, river bottom, and coastline; water conditions; the location of obstructions; and other features of bodies of water. Hydrographic surveys are used for water and land resource planning; erosion, flood, and water level fluctuation analysis; and animal and vegetation assessments. The information obtained during a hydrographic survey is presented on hydrographic maps; nautical charts; and coastal and offshore engineering, zoning, and development maps. Figure 5–9 shows a portion of a hydrographic map created from hydrographic surveying data.

Hydrographic surveys are also used to determine the design characteristics of hydraulic structures, such as bridges, culverts, dams, and docks. This type of survey is sometimes referred to as a **hydraulic survey**. Hydraulic surveys include all data relevant to hydraulic structure design including water surface elevations and flow levels, and elevations of structures.

Photogrammetric Surveys

A **photogrammetric survey** is conducted from photographs, typically aerial photographs, using photogrammetry. **Photogrammetry** is the method of measuring the distance between points on photographs. **Aerial photographs** are photos taken at various altitudes and controlled by base stations at known distances on the ground to check for accuracy. Many overlapping photos are typically required to create an



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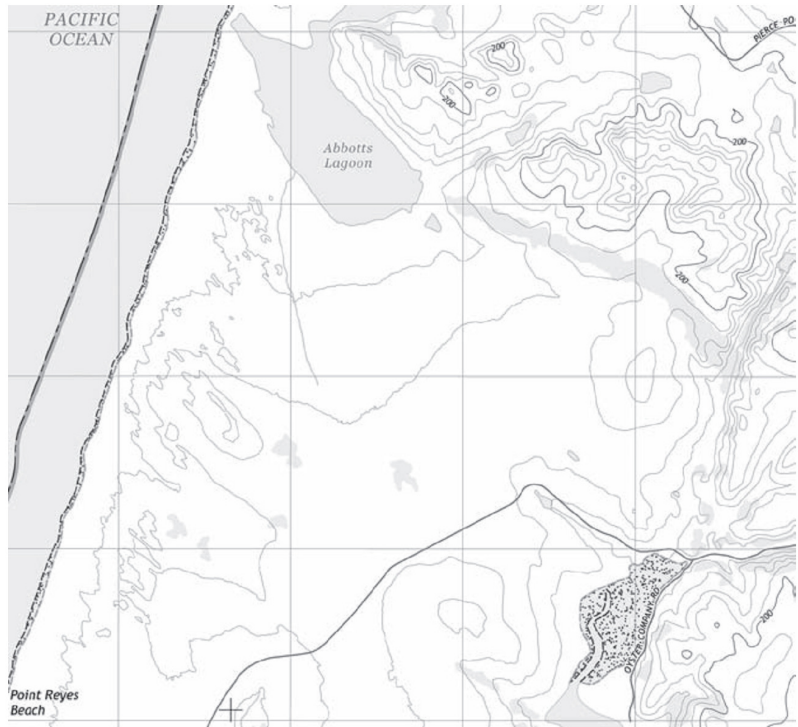


Figure 5-8. A portion of the Drakes Bay, California quadrangle topographic map created using topographic survey data.
(Courtesy of the U.S. Geological Survey)



Figure 5-9. A portion of a hydrographic map at the border of the States of Arkansas and Tennessee produced using hydrographic survey data.
(Courtesy of the U.S. Geological Survey)

accurate map. Aerial photographs can be used to create orthophotos through a process known as rectification, which combines multiple overlapping images and projects the images onto a plane.

Aerial photos are taken at various altitudes to create images at different scales. Aerial photographs taken at a scale from $1'' = 1,000'$ to $1'' = 2,000'$, such as the $1'' = 2,000'$ scale photo shown in Figure 5–10a, are large-area views, have limited accuracy, and are suitable for preliminary planning, agriculture and forestry applications, and county-wide mapping. Aerial photographs taken at a scale from $1'' = 500'$ to $1'' = 1,000'$, such as the $1'' = 1,000'$ scale photo shown in Figure 5–10b, are typically used for preliminary planning, environmental studies, large area development analysis, and drainage studies. Large-scale aerial photographs taken at a scale from $1'' = 100'$ to $1'' = 500'$, such as the $1'' = 200'$ photo shown in Figure 5–10c, offer design-level accuracy, approaching accuracies observed using ground surveying. Applications for this type of aerial photography include highway and airfield design.

Aerial photos are accurately scaled and converted to maps using special stereoscopic instruments and computer software. Aerial orthophotos containing XYZ coordinate data can be used to create civil engineering design and construction drawings. Aerial photographs are also used to compile digital maps that can be used with a CADD system. A photogrammetrist can use a 3-D stereoscopic mapping workstation to see and plot data such as buildings, streets, water edges, and data that is dependent on elevations such as contours, spot elevations, and depressions. A CADD operator can then access this data in digital form by requesting information about specific lines and by reading the coordinates.

Route Surveys

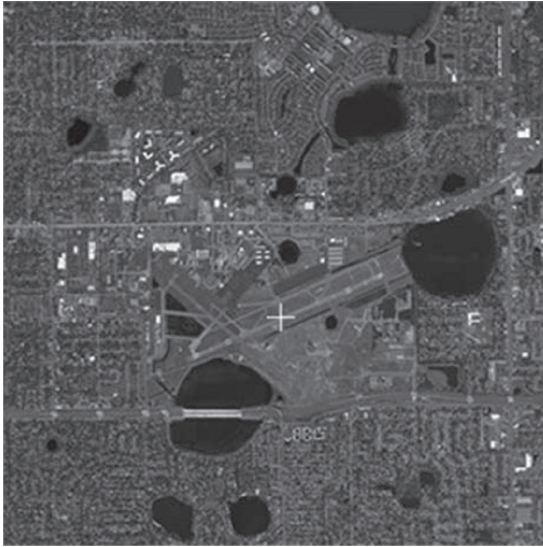
A **route survey** provides accurate location and elevation data of natural and human-made features along a route, such as a road, highway, railroad, or pipeline. The road on which you drive and water supply system from which you drink was surveyed using a route survey. Figure 5–11 shows a drawing of a waterline generated from route survey data.

Construction Surveys

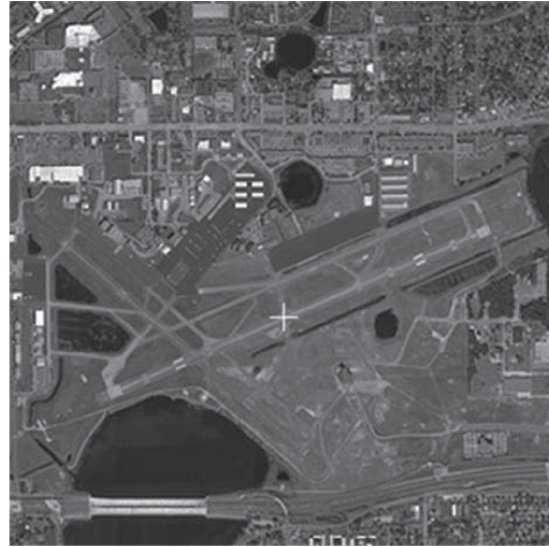
A **construction survey** is performed at a construction site to locate the points and specify the elevations needed during the construction of structures. Construction surveying is one of the most common types of surveying. Construction surveys occur throughout the construction process and establish the locations of building lines and elevations of excavations, fills, foundations, and floors. Figure 5–12a shows a construction survey in progress. Figure 5–12b depicts construction surveying applied during the layout of a small building construction project.

As-Built Surveys

An **as-built survey** is performed after a construction project is finished to identify final construction, including improvements and structures created during construction. As-built surveys provide the



(a)



(b)



(c)

Figure 5-10. (a) An aerial photo with a small scale of $1" = 2,000'$ is appropriate for project plan overview and preliminary studies. (b) An aerial photo with a larger scale of $1" = 1,000'$ and is used for preliminary studies and map design. (c) An aerial photo with a larger scale of $1" = 200'$ is used for engineering and design work.

(Courtesy of the U.S. Geological Survey)

data required to create as-built drawings. An **as-built drawing**, also known as an **as-built**, is drawn after a construction project is finished to document final construction. As-builts can reveal changes made during construction that differ from the design shown in the construction documents. As-built drawings are also referenced for maintenance and operations and future alterations to a structure.

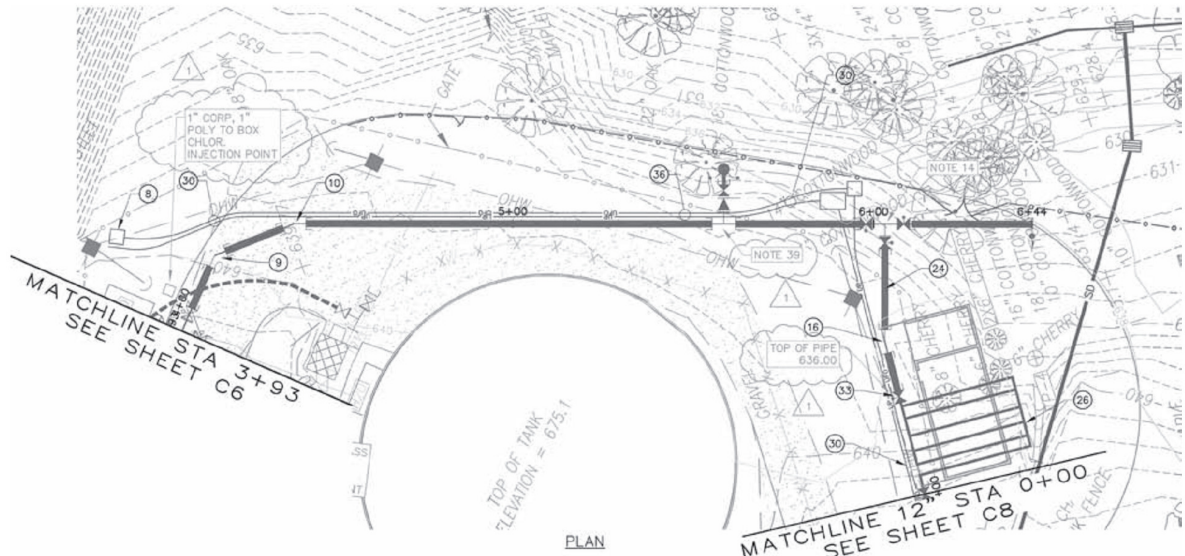


Figure 5-11. A drawing of a waterline created from data collected during a route survey.
(Courtesy of PACE Engineers, Inc.)

Conventional Ground Surveying

Measurement is the basic element of surveying. The measurements taken by surveyors form the basis from which civil engineering projects are planned, designed, and built. The purpose of surveying is to identify locations and measure distances, angles, directions, and volume. Survey data provides the location and elevation of points on the ground and the angular and height relationships between points. The horizontal location of a point on the Earth's surface is often based on geographic latitude and longitude. The elevation of a point is its height above or below a theoretically exact reference point, axis, or surface. You will learn more about location and distances in Chapter 6. The techniques for collecting survey data vary depending on the project requirements. The following information is an introduction to the process of collecting and using the data required for civil engineering projects using conventional ground survey methods.

Data Collection

The **total station** shown in Figure 5-13 is a common piece of conventional surveying equipment used to measure horizontal and vertical distances, and angles. A total station contains an **electronic distance meter (EDM)** that measures distance using infrared or visible laser signals. A surveyor uses a total station to collect, input, work with, and output survey data. Figure 5-14 shows a data collector used with a total station. A surveyor can use a robotic total station and a control unit mounted to a rod with a tracking target to survey an entire job

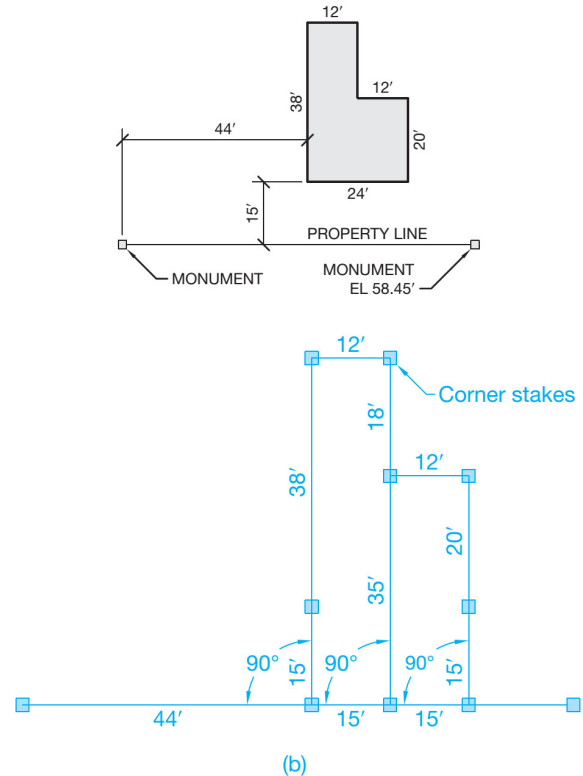


Figure 5-12. (a) A construction survey in progress at a building construction site. (b) The concept of construction surveying showing locations of corners and staking out of a building with distances and angles.
(Figure (a) courtesy of Topcon)

site without assistance. A global navigation satellite system (GNSS) receiver, like the example shown in Figure 5-15, can be employed with the tracking target to provide accurate GNSS data. You will learn more about GNSS later in this chapter.

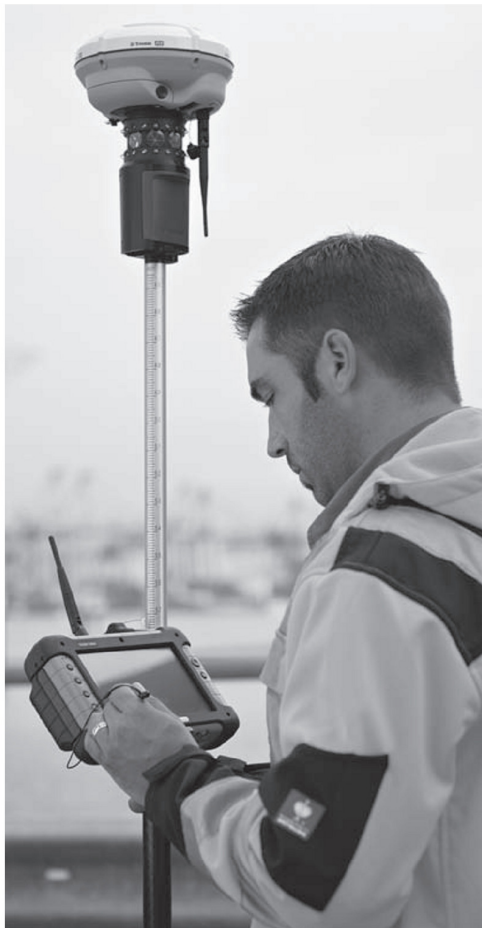
Figure 5-13. A surveyor uses a control unit to operate a robotic total station. A total station measures horizontal and vertical distances and angles.
(Courtesy of Trimble)





Figure 5-14. A data collector transmits information to the total station and stores field data for later download to a computer.
(Courtesy of Topcon)

Figure 5-15. A global navigation satellite system (GNSS) receiver mounted on top of a tracking target provides accurate GNSS data in addition to the horizontal and vertical distance, and angle measurements taken by the total station.
(Courtesy of Trimble)



Observations such as measurements, instrument readings, and calculations made by surveyors in the field are recorded as **field notes**. Field notes were once meticulously recorded by hand in a paper field notebook. Today, the majority of field notes are generated electrically by survey instruments or captured using mobile devices, tablets, and digital cameras. However, it is still common for field crews to record appropriate information in field books. Field notes are important for future reference and as legal evidence. In addition, persons working in the office may have to interpret field notes in order to prepare maps or drawings. Therefore, field notes should be complete, neat, and uncrowded. The following items are important in field notes:

- Title of the survey
- Members of the survey crew
- Location
- Freehand sketches
- Instrument numbers
- Date of survey
- Duty of each crew member
- Weather
- Hand written mistakes crossed out, not erased

Data collected in the field by survey equipment, such as a total station, can be saved as a raw data file in an electronic data collector or field computer (see Figure 5–16). A raw data file contains field notes and a description of each point that was surveyed, known as a **shot**. The data can be edited and the survey adjusted, if necessary, to account for minor systematic errors in measurements. Survey data collection software typically uses proprietary file formats that support interaction between different types of data including total station, GNSS, and image data.

Data Output and Point Coding

Survey data is often stored as raw field measurements and codes. The data can be downloaded at the office into a computer for

Figure 5–16. Data recorded by a total station can be saved in an electronic data collector.
(Courtesy of Trimble)



processing or transmitted directly from the field to the office for processing into XYZ coordinates and attributes. Once processed, survey data is imported into a civil engineering software program, such as AutoCAD Civil 3D, where it is used by civil engineers and drafters to document and design civil engineering projects. Survey data can also be exported to a format such as ASCII text in a text (txt) or spreadsheet (xls) file for transfer between different software programs if necessary. Figure 5–17 shows survey data exported to a spreadsheet (xls) file with a portion of the survey data collected during the survey of a piece of property. The point number, northing and easting distance, elevation, and code of each point appears on a single line, or row. Chapter 6 explains northing, easting, and elevation.

Processed survey data can be used for a variety of applications such as generating a digital terrain model (DTM). A **DTM** typically refers to a vector graphic model created from a collection of 3-D points showing terrain and features that define a change in slope such as a stream or ridge or the edge of a wall or road. Each point mapped during a survey includes a point code that matches the line work code set in the DTM. The point code is the item shown in column E in Figure 5–17. A triangulated irregular network (TIN) represents the topography data of a project from which a DTM can

	A	B	C	D	E
1	1068	1553426.75	1963704.09	4399.8305	BL*BKLS1
2	1069	1553425.19	1963705.58	4400.0811	BKLS1
3	1070	1553424.85	1963711.37	4400.3936	BKLS1
4	1071	1553427.36	1963713.26	4400.4674	EL*BKLS1
5	1072	1553425.5	1963702	4400.5212	VW
6	1073	1553397.46	1963717.38	4401.0323	BL*EP1
7	1074	1553403.68	1963707.18	4400.9437	EP1
8	1075	1553409.7	1963692.25	4400.8755	EP1
9	1076	1553517.27	1963401.56	4401.2147	EL*EP1
10	1077	1553435.13	1963548.34	4401.1215	BL*BLD1
11	1078	1553420.32	1963507.67	4401.1215	BLD1
12	1079	1553455.03	1963495.02	4401.1215	BLD1
13	1080	1553443.36	1963465.57	4401.1215	BLD1
14	1081	1553483.72	1963451.37	4401.1215	BLD1
15	1082	1553499.96	1963497.54	4401.1215	BLD1
16	1083	1553489.43	1963501.37	4401.1215	BLD1
17	1084	1553497.91	1963525.48	4401.1215	CL*BLD1

Figure 5–17. Surveyors can collect at least five pieces of data for a single point and store the data as a text point file.
(Courtesy of Sage Civil Engineering)

be extracted. A **TIN** is a surface model formed by triangulating a set of points. The points, or vertices, are connected with a series of edges to form a network of contiguous triangles that do not overlap.

The points you insert into a drawing from survey data display according to survey point code definitions. Point code specifications are typically based on company, agency, and/or project standards. A survey code usually provides the name of the point or line feature and a line or curve code that links survey points of the same feature. In Figure 5–17, for example, point 1068 has the field code BL*BKLS1. BL* is a line code that indicates the beginning of a line. BKLS1 is a point code for the first breakline surveyed. A **breakline** is a line that defines a change in slope such as a ridge line, the edge of pavement, or a ditch line. Point 1071 has the survey code EL*BKLS1 that indicates the ending (end line) of breakline 1. Point 1073 has the survey code BL*EP1 that specifies the beginning of the first edge of pavement surveyed. Point 1077 has the survey code BL*BLD1 that indicates the beginning of the outline of the first building surveyed. Point 1084 has the survey code CL*BLD1 that designates the closure (close figure) of building 1. As you can see, point codes can be used to describe all elements of a survey.

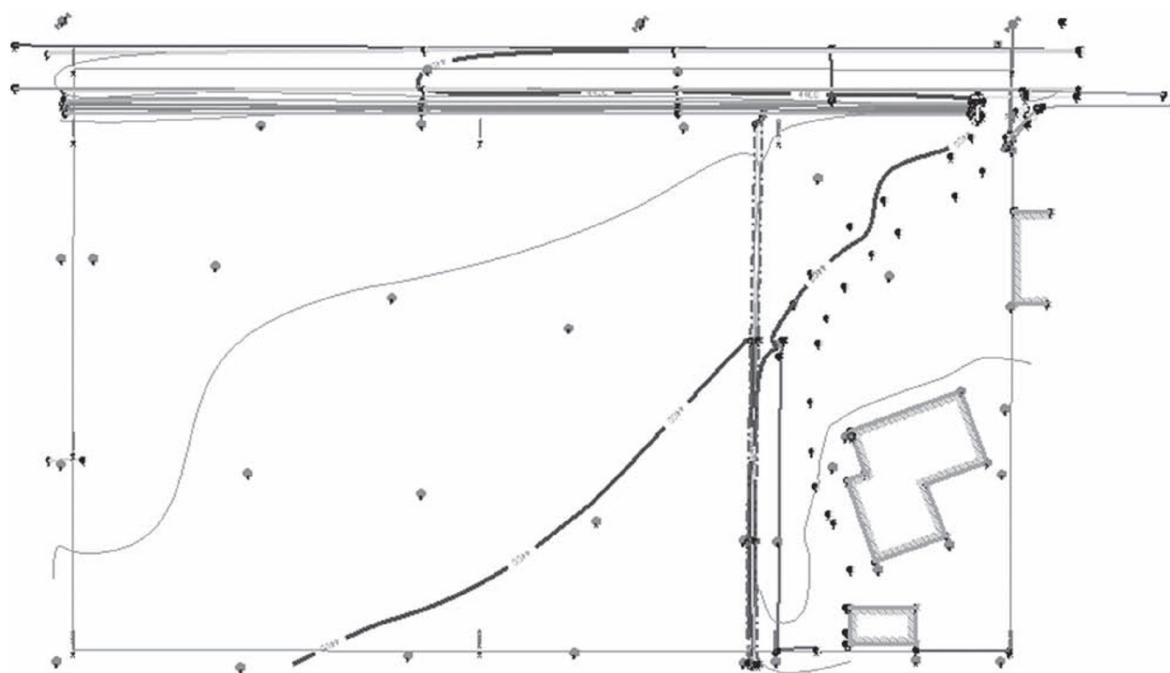
Field point codes specify line conventions used in the drawing such as line weight, type, color, and purpose. Figure 5–18a shows an aerial photo of a site to be surveyed. Figure 5–18b shows the survey processed into a drawing using the points listed in Figure 5–17. Notice the property lines and structures. The parallel lines at the top are edges of the road, irrigation ditch, and utilities; and the contours of the edge of the road. Spot elevations are shown, as are the contours produced from the breaklines and spot elevations. A **spot elevation** is an elevation measurement taken at a single location. Some shots receive a point code that prevents the point from being used in the DTM. For example, a shot taken above ground level, such as at the top of a fire hydrant, will receive a non-DTM point code so that the model does not interpret the height of the fire hydrant as ground level.

Once survey data has been imported into a drawing, project design specifications are applied with software tools to create the drawing layout. For example, you can provide location, elevation, slope, and dimensional data that allow the software to generate features such as streets, curbs, gutters, and sidewalks. CADD software includes tools to create a wide variety of drawings, views, and shaded renderings including profiles of existing grade or new features, such as streets or utilities, and cross sections of roads and other horizontal alignments.

When a design element, such as a building site, dam, or light rail route, is created by engineers and applied to the DTM, a new point file can be generated by the software. Point files can be created for any selected points, alignment, or area. The file is then given to surveyors, who lay out the new points in the field in order for construction to begin.



(a)



(b)

Figure 5-18. (a) An aerial photo of a site to be surveyed. (b) The survey of the property processed into a DTM.

(Figure (a) courtesy of the U.S. Geological Survey, figure (b) courtesy of Sage Civil Engineering)

Global Navigation Satellite System (GNSS)

GNSS is a generic term for any system of satellites that provide global coverage for geographic positioning. The United States maintains the **Global Positioning System (GPS)**, which uses a network of satellites in combination with Earth-based receivers to determine locations on the Earth. The primary functions of GPS are to provide accurate geodetic locations and precise time. GPS was originally developed as a military system but is now available at no charge to civilian users who own GPS receivers.

GPS is used in many civilian applications for locating and recording 3-D positions. GPS has become a vital part of measurement and data collection processes, and its applications may be endless. GPS is used heavily in land surveying. Additional examples of GPS applications are navigation while hiking, driving a motor vehicle, operating a boat or ship, or flying an aircraft; aerospace; emergency rescue; intelligent vehicle systems (IVS); telecommunications; volcanic and seismic research; and natural resource exploration.

GPS Satellites

GPS was developed by the U.S. Department of Defense (DOD) as a worldwide, satellite-based radio-navigation system. The GPS satellite constellation is known as Navigation Signal Timing and Ranging GPS (NAVSTAR). A **satellite constellation** is a network, or group, of satellites. Currently, the satellite constellation consists of 31 operational satellites orbiting about 12,550 mi. (20,200 km) above the Earth (see Figure 5–19). At this altitude, the satellites revolve around the Earth twice in 24 hours. The U.S. Air Force is responsible for maintaining at least 24 operational GPS satellites, 95% of the time. There can

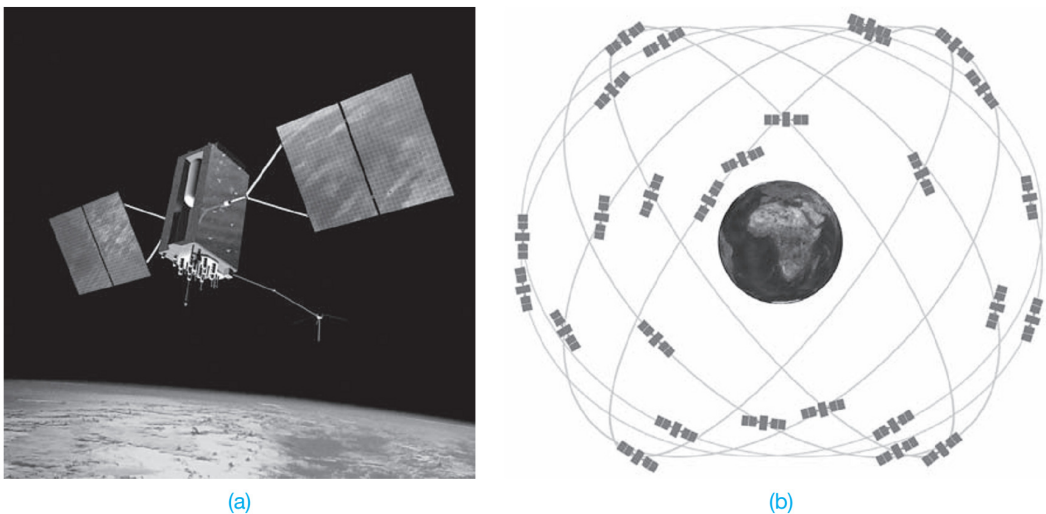


Figure 5–19. (a) A GPS satellite known as the GPS III. (b) The constellation of NAVSTAR satellites orbiting around the Earth.

(Courtesy of the United States Government)

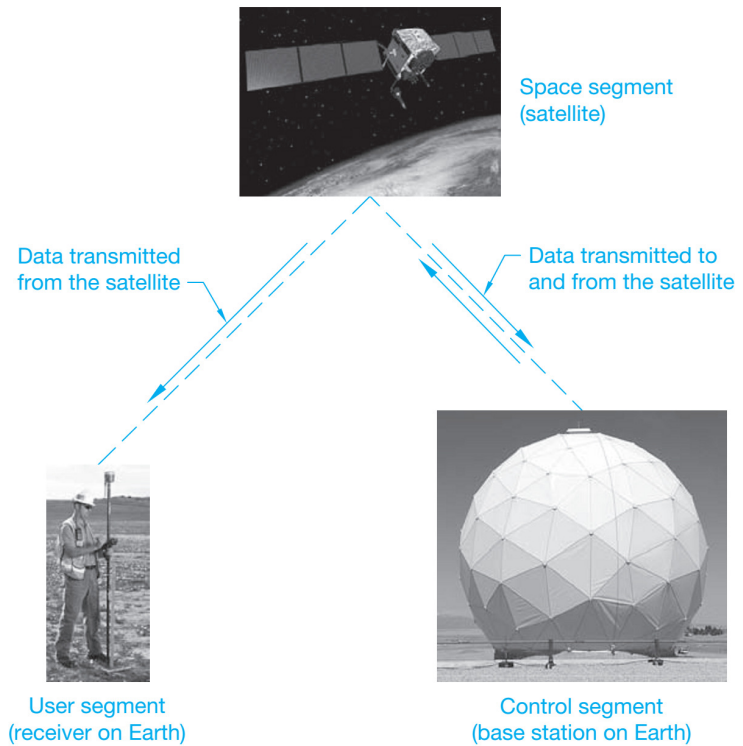


Figure 5–20. How satellites and base stations work together to determine position.

(Base station and satellite image courtesy of the United States Government, receiver image courtesy of Trimble)

be more than the current 31 operational satellites as satellites are launched to replace older satellites.

Note: Other nations have placed satellite constellations in orbit. GNSSs such as the GLONASS system built by Russia and the Galileo system by the European Union are in restoration and development stages. India is currently developing the Indian Regional Navigational Satellite System (IRNSS), and China’s regional Beidou Navigation Satellite System (BDS) is scheduled to be expanded into a global system. Some GNSS receivers, most often high-precision receivers used for surveying and machine control, can use data from multiple systems such as GPS and GLONASS.

Determining Position

GPS has a space segment, control segment, and user segment that come together to provide positional data (see Figure 5–20). The space segment consists of the satellites broadcasting signals at the speed of light. Signals sent from satellites include positional information and precise time.

The control segment is composed of several ground stations located around the world that monitor the positions and health of the satellites. A healthy satellite is in its proper orbit. The GPS master

control station is located at Schriever Air Force Base in Colorado. Base stations measure signals that are developed into orbital models for each satellite. Orbital models compute exact orbital data and clock corrections. The master control station uploads the orbital and clock data to the satellites. The satellites then send the necessary orbital data to the user segment over radio signals.

The user segment consists of the GPS receivers and antennas that receive the satellite signals. GPS receivers are available in chip size and are integrated in small mobile devices as shown in Figure 5–21a. More accurate, survey-grade systems are available in vehicle, backpack, tripod, handheld, and rod-mounted configurations (see Figure 5–21b). Using a principle from algebra, a GPS receiver calculates the distance between itself and a given satellite by determining the amount of time a signal travels from satellite to receiver: Rate speed of light (speed of light) $\times$ Time (determined by receiver) = Distance (from satellite to receiver).

The receiver measures the travel time from four satellites to the receiver to precisely determine position using trilateration. **Trilateration** is the method of establishing a triangle or series of triangles in order to determine the locations of points based on measured distances and two known points. A surveyor on the Earth using a GPS receiver can find the latitude and longitude of a point using the signals from three satellites. Chapter 6 explains latitude and longitude. The elevation of a point, also explained in Chapter 6, is determined using a signal from a fourth satellite. This position is commonly generated by the receiver as a latitude, longitude, and altitude (LLA) coordinate. An example of a GPS position in LLA might appear as:

Lat: 44 32 45.56 N
Lon: 123 14 22.16 W
Alt: 100 Feet



(a)



(b)

Figure 5–21. (a) A handheld mobile device with a GPS receiver. (b) A high-precision GNSS receiver mounted to a tripod.

(Courtesy of Trimble)

GPS Errors, Differential Correction, and Accuracy

The United States once intentionally degraded GPS signals, adding as much as 164' (50 m) of random error to independent GPS positions. This degradation, known as **selective availability (SA)**, was implemented for military security purposes. The removal of SA makes independent GPS positions much more accurate than previously available. However, other natural errors, such as atmospheric signal delays, and satellite and receiver clock drift, still contribute relatively large errors to the travel time from satellites to the receiver, and thus, the positions calculated by receivers.

A wide variety of GNSS/GPS receivers are available, varying greatly in accuracy and cost. Inexpensive handheld receivers can locate you within several feet on a map, but for survey-grade accuracy, also known as subcentimeter accuracy, much more sophisticated equipment is required. Receivers and positioning methods that determine the number of signal wavelengths from satellites to the receiver yield more precise results. Results also vary based on the geometry of the satellite constellation.

Low GPS accuracy with an error range of approximately 50' to 130' (15 to 40 m) is acceptable for some applications such as hiking, but mapping and surveying applications require higher levels of precision. Higher precision, typically to less than 15' (5 m) and 0.4" (1 cm) or less with survey-grade GPS equipment, can be calculated using a technique called **differential GPS**, or **differential correction**. Differential GPS is accomplished using two GPS receivers and mathematically comparing the satellite information collected from both receivers. One GPS receiver is positioned at a known, fixed location called the **base station**. The other GPS receiver, known as the **rover**, is used to collect data at unknown points. The differences between the information collected at the base station and by the rover at the same time are used to calculate the amount of error, or differential. A third method, commonly used in surveying and other precise applications, uses simultaneous observations at two receivers to compute the precise 3-D vector between the receivers. Networks of base stations established by the public and private sectors in some areas allow the collection of survey-grade data with just one GPS receiver, thereby eliminating the need for each person collecting GPS data to invest in an expensive base station. Figure 5–22 shows general features of recreational, geographic information system (GIS)-grade, and survey-grade GPS receivers. Chapter 14 describes GIS.

Note: There are different GPS surveying techniques including static, rapid static, kinematic, pseudo-kinematic, and real-time kinematic (RTK). Surveyors generally select the appropriate GPS surveying method based on project and accuracy requirements, terrain, and available equipment.

Receiver Type	Autonomous Accuracy	Accuracy Using Statistic Differential Method	Feature Types	GIS Collection and Export	Applications	Typical Cost
Recreational	49–131' (15–40 m) (2 RMS*)	Differential GPS generally not available	Points	No	Course navigation and recreation	\$50–\$1,500
GIS-grade	49–131' (15–40 m) (2 RMS*)	3–16' (1–5 m) to < 3' (1 m) (2 RMS*)	Points, lines, polygons. Lines and polygons are digitized in the field.	Feature, attribute, value lists supported. Standard GIS and CADD software formats supported for export.	Resource mapping and GIS data collection inventories	\$1,000–\$10,000
Survey-grade	49–131' (15–40 m) (2 RMS*)	0.4" (1 cm) + 1 ppm** (2 RMS*)	Points, lines, polygons	Varies with model. Some support full GIS capability found in GIS-grade systems.	Surveying	\$10,000–\$30,000
* RMS = Root mean square describes statistical confidence. 2 RMS refers to 95% confidence. ** ppm = Parts per million refers to the degradation of accuracy as the distance between the base station receiver and the data collection receiver (rover) is extended.						

Figure 5–22. General features of recreational, GIS-grade, and survey-grade GPS receivers.

Aerotriangulation

Aerotriangulation is the method of associating aerial photographs to known ground control points. One example of aerotriangulation incorporates a GPS antenna mounted over the camera on the fuselage of the aircraft and ground-based GPS receivers to link the position of the camera to a known coordinate reference frame. Each time the camera takes a photograph, a pulse is sent to the onboard GPS receiver. The aerial system records a precise timestamp for each camera exposure. GPS receivers on the camera and ground ensure accurate recording of data. Sophisticated software handles mathematical interpolation for the lack of time synchronization between camera exposure and GPS signal recording. **Interpolation** is the process of inserting missing values between given numbers. Interpolation between GPS position observations produces the camera position at the exact time of exposure. In addition, software routines for 3-D Earth curvature help to reduce errors. Aerotriangulation still requires that ground surveys establish control points for accuracy, but the number of ground control points is greatly reduced because of the accuracy of the GPS data and procedures.

3-D Laser Scanning

The majority of data collected for civil engineering projects comes from conventional surveying methods. However, newer technologies are becoming increasingly common. 3-D laser scanning is used as an alternative or a complement to conventional ground surveying and other forms of data collection such as traditional photogrammetry. **3-D laser scanning**, also known by other terms such as

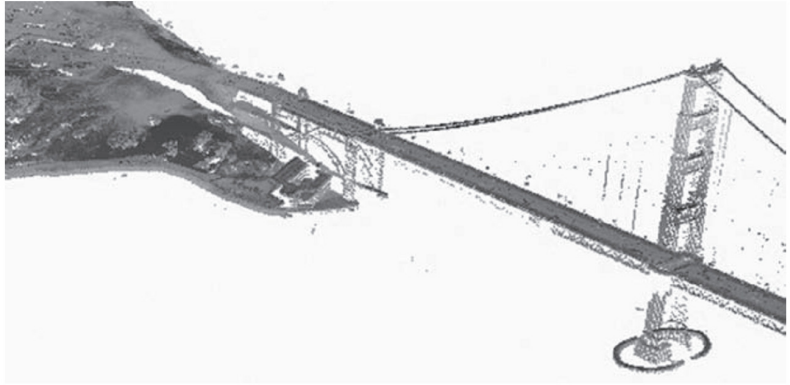


Figure 5–23. A 3-D LiDAR point cloud image of San Francisco Bay and Golden Gate Bridge in California state.

(Courtesy of the U.S. Geological Survey)

Light Detection and Ranging (LiDAR), is the method of collecting detailed 3-D information using a laser scanner that passes a laser over the surface of an object or area. A **3-D laser scanner** is a device that uses a laser light beam to measure distances. A sensor inside the laser scanner can collect thousands or millions of 3-D point measurements in one second. Some companies and agencies routinely use 3-D laser scanning for civil engineering projects.

Laser scanning quickly produces detailed 3-D point clouds. A **point cloud** is a mass of 3-D XYZ coordinate point data. Figure 5–23 show an example of a 3-D LiDAR point cloud image. Many users work directly with point cloud data. Point clouds can also be processed using specialized software to create 3-D models and DTMs. Laser scanning and point cloud data is used for a variety of applications from producing 3-D models of existing buildings, bridges, tunnels, and topographic features to capturing photorealistic detail required in worksite evaluation, historic restorations, and crime scene and accident forensics. There are different types of laser scanning technologies and laser scanners. Surveyors use stationary ground-based, mobile ground-based, and airborne laser scanners depending on projects requirements.

Stationary Ground-Based Laser Scanning

Stationary ground-based laser scanning, also known by other terms such as **static terrestrial laser scanning** and **high-resolution surveying**, is a 3-D laser scanning technology that uses a laser scanner typically set up on a tripod, like a conventional ground survey instrument, and pointed toward the area to be scanned (see Figure 5–24). The scan covers a specific field of view, in degrees, horizontally and vertically. If a larger area is required than can be covered in a single scan, the instrument is repositioned and another scan is taken. Multiple scans can be stitched together with software to produce a single point cloud and subsequent 3-D model. Figure 5–25a shows a point cloud and color perspective of a building produced using a static laser scanner. Static laser scanners usually

Figure 5–24. A surveyor using a stationary ground-based 3-D laser scanner to scan a construction site.
(Courtesy of Trimble)

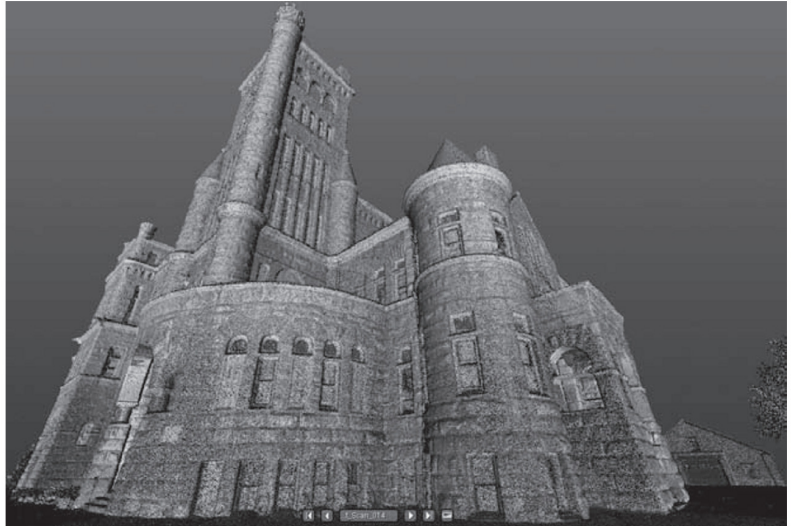


integrate digital cameras that collect imagery during the scanning process. Figure 5–25b shows how georeferenced images captured by the scanner can be draped over the point cloud to produce photorealistic 3-D models. A **georeferenced image** is the result of associating objects with locations on the Earth using a geodetic or other coordinate system.

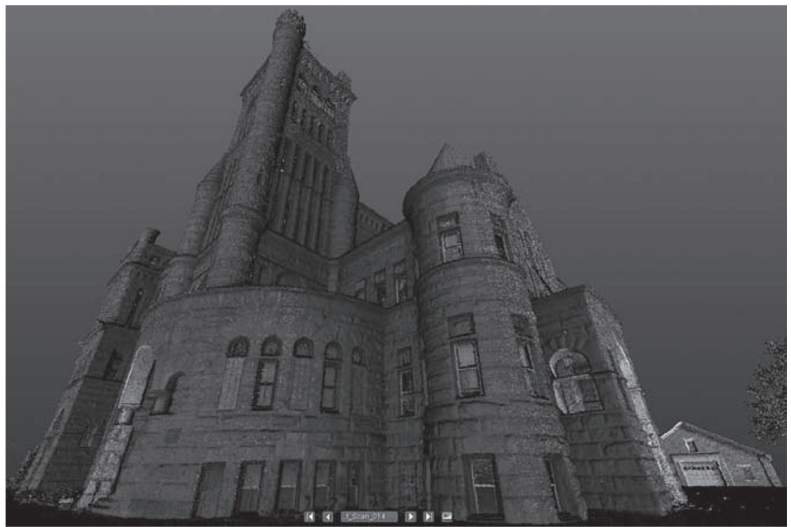
One example of a static laser scanning application is an urban in-fill project when constructing a new building next to an existing building. The 3-D scan shows irregularities in the older, existing wall, which is critical for locating the new wall. Static laser scanning allows surveyors to collect a large amount of accurate data in a very short amount of time compared to conventional ground surveying, which reduces the amount of time surveyors spend in the field, and thus increases safety and cost-effectiveness. Static laser scanning provides higher resolution and accuracy than mobile ground-based and airborne laser scanning (ALS).

Mobile Ground-Based Laser Scanning

Mobile ground-based laser scanning, also known by other terms such as **mobile terrestrial laser scanning**, **mobile laser scanning (MLS)**, and **mobile mapping**, is a 3-D laser scanning technology that uses a laser scanner, typically with multiple laser sensors, and odometers, wheel and internal sensors, and digital cameras with GNSS receivers, attached to a moving vehicle such as a car, truck, railcar, or all-terrain vehicle (ATV). Figure 5–26 shows an example of an MLS system. One example of an MLS application is surveying roadways where features such as existing buildings, bridges, power and telephone lines, and trees and other vegetation need to be considered. MLS allows surveyors to collect a large amount of data in a very short amount of time without having to reposition the scanner as is the case with static laser scanning. MLS provides higher resolution and



(a)



(b)

Figure 5–25. (a) A point cloud and color perspective of a building produced using a 3-D laser scanner. (b) Georeferenced images captured by the scanner can be draped over the point cloud to produce a photo-realistic 3-D model.

(Courtesy of Trimble)

precision than ALS and offers even greater safety and potential cost-effectiveness compared to static laser scanning.

Airborne Laser Scanning

ALS, or **aerial laser scanning**, is a 3-D laser scanning technology that uses a laser scanner, typically with multiple laser sensors and digital cameras with GNSS receivers and inertial measurement units (IMUs),

Figure 5–26. A mobile ground-based, or mobile terrestrial, scanning system.
(Courtesy of Trimble)



attached to an aircraft or spacecraft. An **IMU** is a device that measures linear acceleration and angular rotation using three gyroscopes and three accelerometers. Surveys for civil engineering projects most often use lower-altitude methods of ALS, typically conducted from crewed or unmanned fixed-wing aircraft or helicopters. Figure 5–27 shows data collected using ALS.

One example of an ALS application is surveying large open pit mines to make volume calculations. ALS allows surveyors to collect a large amount of data in a very short amount of time without being limited to a path as is the case with MLS. ALS can capture geospatial data that is more precise than data collected using photogrammetry, and unlike photogrammetry, ALS can produce accurate ground images through clouds and at night.

Note: In general, and when practical, surveyors select the most appropriate technologies and practices for a particular project. Conventional survey techniques are well established and understood. Conventional survey control points are often coupled with 3-D scan data to supply required accuracy. In addition, conventional ground surveys provide data that cannot be collected using newer technologies. For example, a 3-D scan typically does not provide below ground information such as the size and depth of a utility line or manhole.



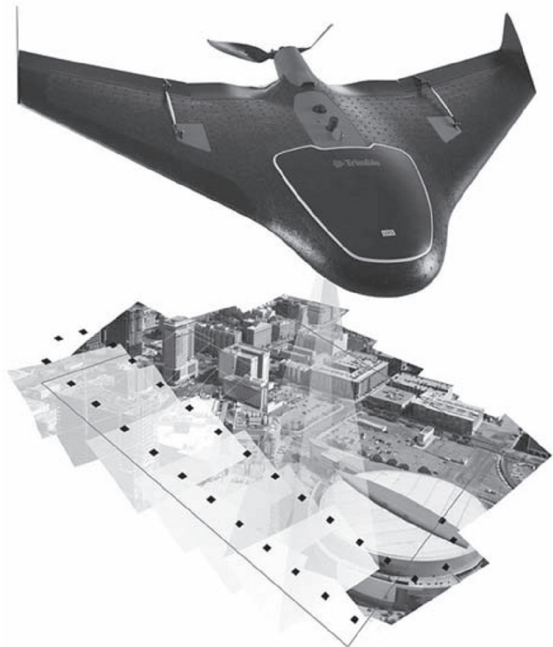
Figure 5–27. A 3-D LiDAR point cloud image of a portion of the District of Columbia including the Washington Monument and the White House.

(Courtesy of the U.S. Geological Survey)

Remote Sensing

Remote sensing refers to the detection of information about an object or experience, without actually contacting the object or experience. In reference to mapping, the term remote sensing has been applied to the use of highly sophisticated instruments, typically carried by vehicles, ships, aircraft, and spacecraft, to collect information about the surface of the Earth. The data obtained by remote sensing instruments is used by scientists and engineers to generate a variety of maps and images, especially of large areas. Aerial photography and 3-D laser scanning are common examples of remote sensing. Other technologies applied to remote sensing include radar and multi-spectral and infrared imagery. Applications for remote sensing range from mapping inaccessible areas to the creation of thematic maps.

Remote sensing has been conducted using fixed-wing aircraft, helicopters, and satellites for many years. Recently, the use of unmanned aerial vehicles (UAVs) has been applied to remote sensing. An **UAV**, also known by other terms such as **unmanned aerial system (UAS)** and **drone**, is an aircraft operated by remote control or computer without an onboard human pilot. Figure 5–28 shows an example of a fixed-wing and a rotary-wing UAV. UAVs can be used to collect a variety of data, generally at lower altitudes and closer to obstacles than manned aircraft, and without endangering the crew of a manned aircraft, especially in difficult terrain. The UAVs shown in Figure 5–28 can carry digital and infrared cameras for capturing high-definition photographs and videos and infrared images. Some UAVs carry GNSS receivers to establish accurate image locations. 3-D laser scanning UAV systems are also available. Common examples of UAV remote sensing applications are inspecting utilities, equipment, and structures; and photogrammetric survey of smaller sites.



(a)



(b)

Figure 5-28. (a) A fixed-wing UAV and the concept of aerial mapping conducted using a UAV. (b) A rotary-wing UAV taking photographs and videos during the inspection of a bridge.
(Figure (a) courtesy of Trimble, figure (b) courtesy of Topcon)

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

5-1 Define surveying.

5-2 Who is a surveyor?

5-3 What is the science of measuring the size and shape of the Earth?

5-4 Geodetic surveys are appropriate for surveying areas generally greater than how many square miles or kilometers?

5-5 What is triangulation?

5-6 What is a bench mark and what is the abbreviation for a bench mark?

5-7 Define plane survey and specify the size of the general area appropriate for surveying using a plane survey.

5-8 What type of mathematical calculations is used in a plane survey?

5-9 Define land survey.

5-10 What is a topographic survey?

5-11 What data does a hydrographic survey provide?

5-12 What are aerial photographs, and for what can they be used?

5-13 What type of survey would be used to lay out a new highway?

- 5-14** Define construction survey.
- 5-15** What type of drawing is drawn after a construction project is finished to document final construction?
- 5-16** The purpose of surveying is to identify locations and measure what values?
- 5-17** Name at least four pieces of data about a point that can be recorded by a total station and stored in an electronic data collector or field computer.
- 5-18** What is a digital terrain model and what is the abbreviation for a digital terrain model?
- 5-19** What is the generic term for any system of satellites that provide global coverage for geographic positioning?
- 5-20** Briefly explain how the global positioning system is used to determine position.
- 5-21** What is aerotriangulation?
- 5-22** List the three primary types of 3-D laser scanning methods used by surveyors.
- 5-23** What is another name for mobile ground-based laser scanning?
- 5-24** Define remote sensing.
- 5-25** What is an unmanned aerial vehicle?
- 5-26** In what type of survey is triangulation used?

PROBLEMS

Follow the specific instructions to complete each problem.

P5-1 Describe five examples of projects that require surveying.

P5-2 Identify and explain the function of the surveying equipment shown in Figure P5-2.



(a)



(b)



(c)

Figure P5-2.
(Courtesy of Topcon)

P5-3 Identify and explain the function of the surveying equipment shown in Figure P5-3.



(a)



(b)



(c)

Figure P5-3.
(Courtesy of Topcon)

P5-4

1. SURVEY PROVIDED BY KPFF AND KELLER ASSOCIATES, DATED MARCH 5, 2010. VERTICAL DATUM NGVD 88, BASED ON A GPS OPUS-RS SOLUTION FROM THE NATIONAL GEODETIC SURVEY (GEIOD 03).
2. SOME SITE DEMOLITION AND UTILITY RELOCATION HAS BEEN PERFORMED. SURVEY MAY NOT BE COMPLETE OR ACCURATE. CONTRACTOR TO VERIFY EXISTING SITE CONDITIONS PRIOR TO CONSTRUCTION. CONTRACTOR SHALL BRING ANY DISCREPANCIES TO THE ATTENTION OF THE CONTRACTING OFFICER PRIOR TO BEGINNING CONSTRUCTION.
3. MAINTAIN POSITIVE DRAINAGE AWAY FROM BUILDING. MATCH PROPOSED SURFACE FEATURES TO EXISTING GRADES.
4. POWER IS PROVIDED TO THE BUILDING VIA AN OVERHEAD LINE. CONTRACTOR SHALL COORDINATE WITH IDAHO POWER FOR SERVICE RECONNECTION.
5. RECONNECT POTABLE WATER TO EXISTING WELL WITHIN WELL PIT USING EXISTING SERVICE. SANITARY SEWER SERVICE WILL BE PROVIDED BY THE INSTALLATION OF A NEW SEPTIC TANK AND DRAIN FIELD.

- ① ACCESSIBLE RAMP AND STAIRS PER ARCHITECTURAL PLANS WITH PEDESTRIAN CONCRETE PAD AT LANDING. SEE DETAIL FOR PAVEMENT SECTION.
- ② PROVIDE CONCRETE PAD FOR ACCESSIBLE PARKING STALL AND LANDING WITH SIGNAGE FOR ACCESSIBLE PARKING STALL. STRIPING SHALL BE 4" WIDE, WHITE PAINT STRIPES. SLOPE SHALL NOT EXCEED 2% IN ANY DIRECTION.
- ③ PROVIDE ACCESSIBLE PATH. COORDINATE WITH PARK FOR GRAVEL SECTION AND INSTALLATION REQUIREMENTS. PATH SHALL MATCH EXISTING GRADE AND PROVIDE POSITIVE DRAINAGE AWAY FROM BUILDING.
- ④ EXISTING WELL AND PUMP. CONDITION AND REUSE TO BE DETERMINED BY OTHERS.
- ⑤ PROVIDE 4" THICK CONCRETE HOUSE KEEPING PAD WITH 3" THICK BASE COURSE. LOCATION PER ARCHITECTURAL PLANS.

 CONCRETE PAVEMENT
 ACCESSIBLE GRAVEL PEDESTRIAN PATH
 6" VEHICULAR GRAVEL
 XXX.XX FG FINISHED GRADE (FG) SPOT ELEVATION
 X% SURFACE SLOPE



(Courtesy of KPFF Consulting Engineers)

- P5-5** Describe the image shown in Figure P5-5 and the technology used to capture the data. Explain how you came to your conclusion.



Figure P5-5.

(Courtesy of the U.S. Geological Survey)

- P5-6** Write a report of approximately 250 words describing your experience and use of global navigation satellite system (GNSS) technology.
- P5-7** Interview a surveyor at a local surveying or civil engineering company to learn more about surveying, including a description of the skills required to be a surveyor, the most common types of surveys conducted by the surveyor, and a typical day as a surveyor. Write a report of approximately 250 words covering what you learn. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.
- P5-8** Locate and take a digital photograph of a survey bench mark. Write a report of approximately 250 words describing the process required to find the bench mark. Prepare a PowerPoint presentation of your quest and present the slide show to your class or office. Include the photograph of the bench mark with your report and presentation.



CHAPTER

6

Locations and Distances

Learning Objectives

After completing this chapter, you will be able to:

- Use the Cartesian coordinate system to locate points.
- Apply the geographic coordinate system to locate points.
- Approximate the distance between locations given latitude and longitude.
- Describe examples of common map projections.
- Use the Universal Transverse Mercator (UTM) and State Plane Coordinate System (SPCS) to locate points.
- Identify and describe instruments used to measure horizontal and vertical distances.
- Identify and read the markings of a level rod.
- Calculate leveling field notes to determine instrument heights and unknown elevations.
- Describe the function of laser levels.

Key Terms

Location
Coordinate system
Cartesian coordinate system
Origin
Rectangular coordinate system
Oblate spheroid
Datum
Geodetic datum
Geocentric datum
Geographic coordinate system
Lines of latitude
Parallels of latitude
Parallels
Lines of longitude
Degree
Sexagesimal system
North latitude
South latitude
Statute mile
Meridians
Prime meridian
East longitude
West longitude
Spherical triangle
Great circular arcs
Radian
Spherical excess
Spherical trigonometry
Map projections
Map coordinate system
Universal Transverse Mercator (UTM)
(continued)

Key Terms (*continued*)

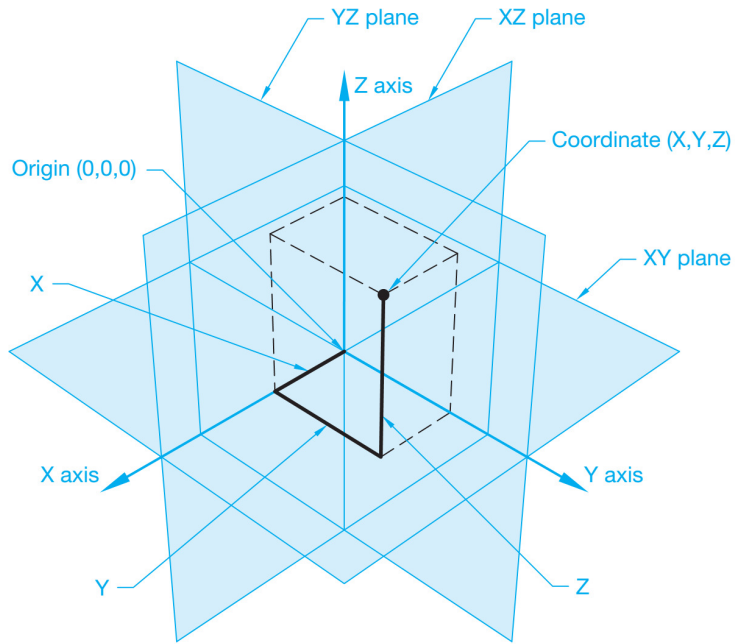
State Plane Coordinate System (SPCS or SPS)	Chaining	Backsight (BS)
U.S. survey foot	Plumb bob	Height of the instrument (HI)
Quadrangle map	Breaking chain	Foresight (FS)
Margin	Stadia	Intermediate foresight (IFS)
Collar	Elevation	Local control points
Credit legend	Vertical datum	Temporary bench marks (TBMs)
Tick mark	Bench mark (BM)	Turning point (TP)
Electronic distance measuring instrument (EDMI)	Mean sea level (MSL)	Self-reading rods
Electronic distance meter (EDM)	Leveling	Optical-micrometer level
Corner cube prism	Direct leveling	Rotating beam laser level
Pacing	Spirit leveling	Rotating laser level
Pedometer	Differential leveling	Pipe laser level
Measuring wheel	Surveyor's level	Line laser level
Odometer	Level rod	Plumb laser level
Taping	Level pole	Laser detector
	Level staff	Laser receiver
	Footplate	

Location specifies a geographic point or area. Identifying locations and measuring the distance between locations are fundamental concepts associated with most civil engineering and drafting applications. This chapter explains systems used to define the location of points. You will also learn about measuring horizontal and vertical distances between points.

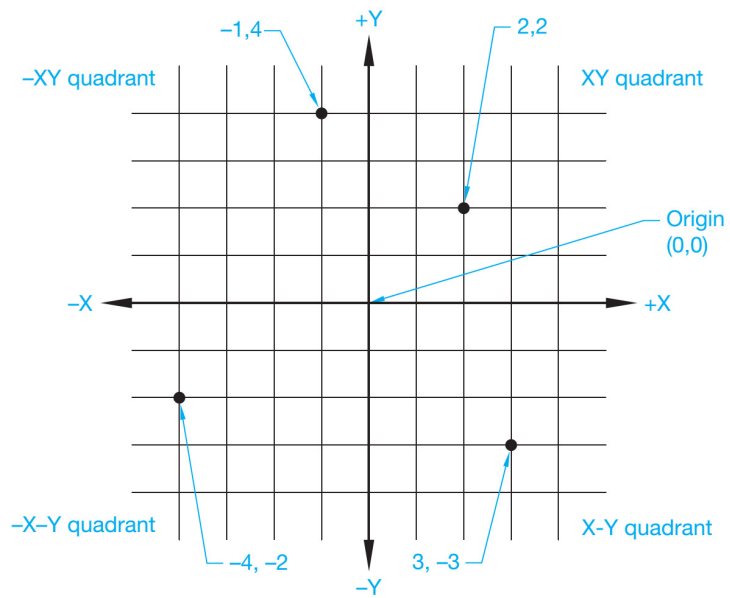
Cartesian Coordinate System

A **coordinate system** is a method that uses numbers, or coordinates, to specify the location of points in space. A common example of a coordinate system is the Cartesian coordinate system. The **Cartesian coordinate system** locates points in three-dimensional (3-D) space according to distances from intersecting *X*, *Y*, and *Z* axes (see Figure 6–1 a). The **origin** is the point where the *X*, *Y*, and *Z* axes intersect, or 0,0,0. In 2-D drafting, the *X* and *Y* axes divide the coordinate system, known as the **rectangular coordinate system**, into four quadrants on the *XY* plane (see Figure 6–1 b). To locate a point in 3-D space, a third dimension rises up from the surface of the *XY* plane along the *Z* axis. A coordinate is described by the *X* value first, followed by the *Y* value, and finally the *Z* value. A comma separates each value. For example, the coordinate location of 120,36,48 represents a point that is 120 units from the origin in the *X* direction, 36 units from the origin in the *Y* direction, and 48 units from the origin in the *Z* direction.

As explained in Chapter 5, the Earth is an **oblate spheroid**, which is a flattened 3-D ellipse, or ellipsoid, that rotates around the minor axis. The Cartesian coordinate system can be applied to locate a point anywhere on the Earth's surface with the origin, or datum, at the center of the Earth (see Figure 6–2). A **datum** is a theoretically exact reference point, axis, or plane. A **geodetic datum** is a system associated with a reference surface used to provide known



(a)

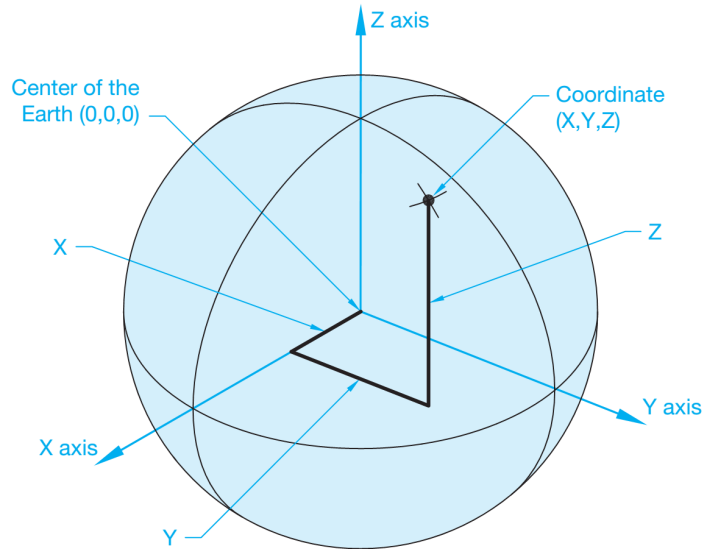


(b)

Figure 6-1. (a) The *Cartesian coordinate system* locates points in three-dimensional (3-D) space according to distances from intersecting X, Y, and Z axes. (b) In 2-D drafting, the X and Y axes divide the coordinate system into four quadrants on the XY plane.

locations. A **geocentric datum** specifies the center of the Earth at the Earth's center of mass. The World Geodetic System of 1984 (WGS 84) datum is a standard geocentric datum used for many mapping and navigation applications. The WGS 84 datum is based on

Figure 6-2. Using Cartesian coordinates to identify the location of a point on the surface of the Earth.



satellite-based measurements of the Earth. There are also many local datums intended to provide greater accuracy at specific locations. For example, the North American Datum 1983 (NAD 83), used for many U.S. maps, is a geocentric datum based on measurements taken from the Geodetic Reference System 1980 (GRS 80). The GRS 80 ellipsoid is slightly different than the WGS 84 ellipsoid.

Geographic Coordinate System

The **geographic coordinate system** is a coordinate system that establishes the location of points on the Earth using the degrees of a circle as reference. If the Earth was flat, the geographic coordinates of a location could be identified using a plane, or flat, coordinate system. However, the Earth is an oblate spheroid, and as a result, accurate measurements are made from points at the north and south poles and the equator. An imaginary grid system has been established based on these three references. The grid lines are referred to as lines of latitude and longitude.

Lines of latitude, also known as or **parallels of latitude** or **parallels**, are imaginary parallel lines that circle the Earth horizontally. **Lines of longitude** are imaginary lines that circle the Earth vertically, and pass through the north and south poles. Lines of latitude and longitude are measured as an angular distance in degrees from the center of the Earth. A **degree** is a unit of angular measurement. Degrees are identified with the degree ($^{\circ}$) symbol, such as in 50° . There are 360° in a complete circle, 90° in a quarter of a circle, 180° in half of a circle, and 270° in three-quarters of a circle.

A degree is divided into fractions using the sexagesimal system. The **sexagesimal system** is a numerical system based on the division of 60. Each degree is made up of 60 minutes. Minutes are identified by the minutes ($'$) symbol, such as $30'$. Minutes are divided into 60

seconds. Seconds are identified by the seconds (") symbol, such as 45". An example of a complete degrees minutes seconds designation is 50°30'45". The U.S. National Geodetic Survey (NGS) uses the sexagesimal system to specify degrees. Chapter 7 explains more about angular measurements.

Latitude

Lines of latitude are parallel to the equator and are identified by degrees north or south of the equator. The equator represents 0° latitude. The north pole is 90° north latitude, and the south pole is 90° south latitude (see Figure 6–3). Parallels north of the equator are referred to as **north latitude**. Paris, France, for example, is located 48°51'24" north latitude, which is specified as 48°51'24"N. Parallels south of the prime meridian are called **south latitude**. Buenos Aires, Argentina, for example, is located 34°36'12" south latitude, which is specified as 34°36'12"S.

The bulging of the Earth near the equator causes the distance of each degree of latitude to vary slightly, from 69.4 mi. near the poles, to 68.7 mi. at the equator. For all but very detailed maps, it is suitable to specify each degree of latitude as 69 statute miles in length. A **statute mile** equals 5,280 ft.

Longitude

Lines of longitude are also referred to as **meridians**. The **prime meridian** is the imaginary line passing through the north and south poles and Greenwich, England. The prime meridian represents 0° longitude. There are 180° west and 180° east of the prime meridian, forming the full circle of 360° around the Earth (see Figure 6–4). Meridians east of the prime meridian are referred to as **east longitude**. Paris, France, for example, is located 2°21'03" east

Figure 6–3. Imaginary lines of latitude circle the Earth parallel to the equator.

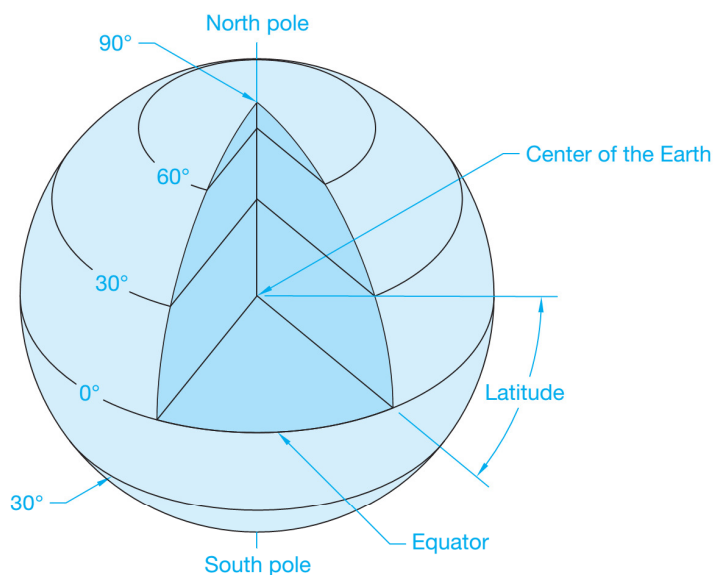
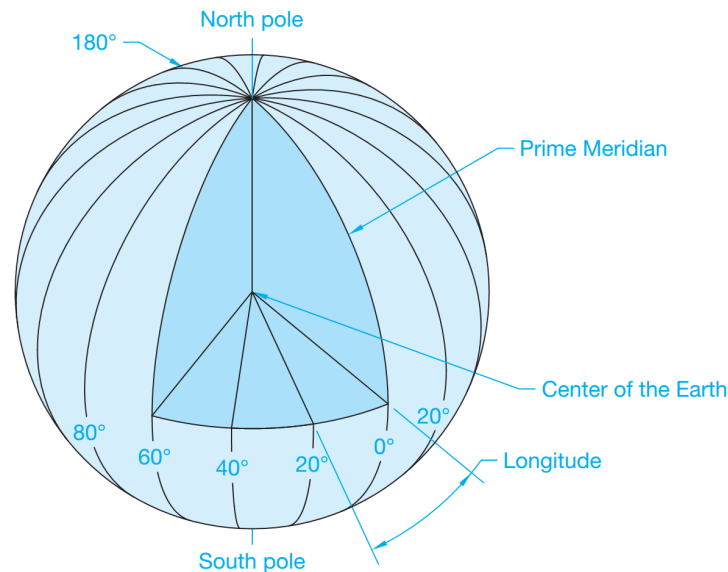


Figure 6-4. Imaginary lines of longitude circle the Earth vertically and pass through the north and south poles.



longitude, which is specified as 2°21'03"E. Meridians west of the prime meridian are called **west longitude**. Buenos Aires, Argentina, for example, is located 58°22'54" west longitude, which is specified as 58°22'54"W. The 180° meridian coincides roughly with the international date line. The date is one day earlier east of the international date line.

As you can see in Figure 6-4, a degree of longitude varies in length at different parallels of latitude, becoming shorter as the parallels approach the north and south poles. Figure 6-5 shows the length of one degree of longitude at certain latitudes. Use the following formula to calculate the length of a degree of longitude using the approximate value of 69 mi. per degree of latitude:

$$\begin{aligned} \text{Length of a degree of latitude} \times \text{Cosine latitude} &= \\ \text{Length of a degree of longitude} \end{aligned}$$

For example, apply the following calculation to determine the length of a degree of longitude at 45° latitude:

$$\begin{aligned} \text{Length of a degree of longitude} &= 69 \text{ mi.} \times \text{Cosine } 45^\circ = \\ 69 \times 0.70711 &= 48.791 \text{ mi.} \end{aligned}$$

Latitude	Statute Miles
0°	69.186
10°	69.128
20°	65.025
30°	59.956
40°	53.063
50°	44.552
60°	34.674
70°	23.729
80°	12.051
90°	0.000

Figure 6-5. The length of one degree of longitude at specific latitudes.

Locations on Maps

On flat maps, parallels and meridians can appear as either curved or straight lines. Most maps are drawn so north is at the top, south at the bottom, west at the left, and east at the right. Look for the north arrow symbol for the orientation. Use the coordinates of parallels and meridians to determine locations and directions on a map. For example, look at the map of the State of Iowa shown in Figure 6-6 to see that the City of Mason City is north of the City of Des Moines and west of the City of Cedar Rapids. Any location on the Earth can be identified by locating its intersecting lines of latitude and longitude.

There are different ways to calculate the distance between two points on the Earth's surface with specified latitudes and longitudes,

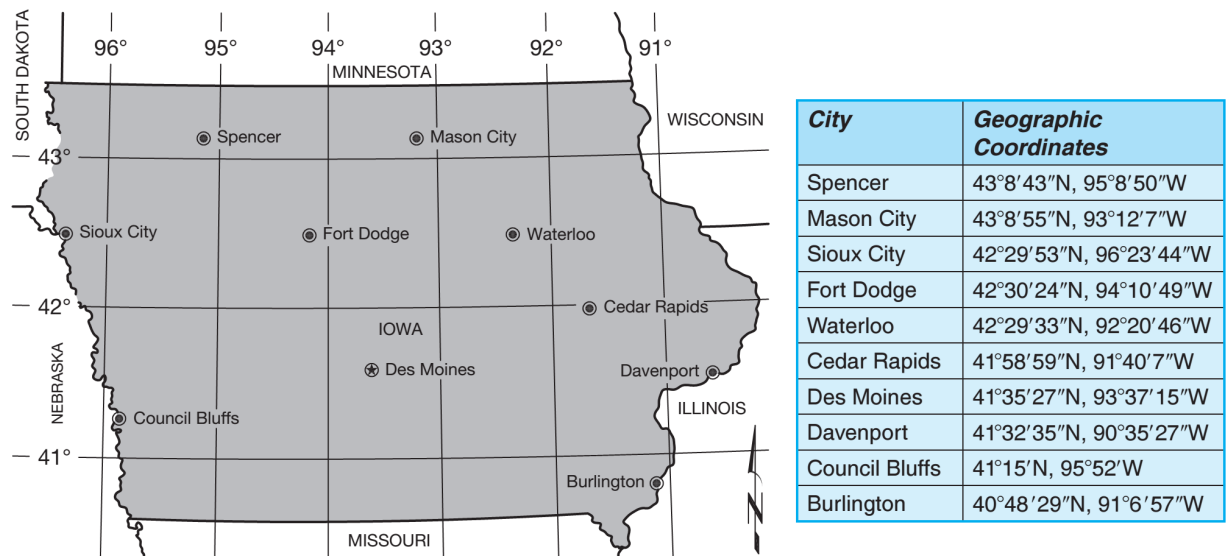


Figure 6-6. Using meridians and parallels to identify the locations of cities in the State of Iowa.

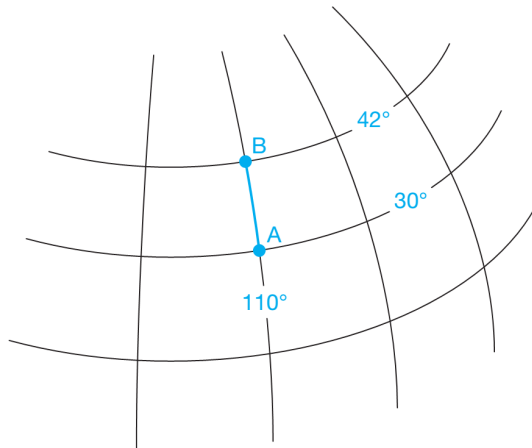
depending on the distance between the points. When two points lie on either the same parallel or the same meridian, you can use the length of a degree of latitude to find the distance between the points. If the points are fairly close, such as a few hundred miles or less from each other, you can imagine the Earth's surface as being flat and use the Pythagorean theorem to find distance. Generally, when points are a great distance away from each other, the shape of the Earth becomes an issue, and a spherical triangle must be solved in order to identify distance.

Note: Civil engineering projects that involve relatively short distances, areas generally less than three square miles, are established with plane survey methods. The following is valuable information and gives you important background knowledge. However, calculating far distances, generally over three miles, on the Earth's surface is usually reserved for aeronautical, geodetic, nautical, space navigation, and astronomical applications.

Distances Between Locations on the Same Parallel or Meridian When two points lie on either the same parallel or the same meridian, you can use the length of a degree of latitude to find the distance between the points. If the points are on the same meridian, first calculate the number of degrees of latitude between the points and then multiply by the length of a degree of latitude. The following are two examples that use the approximate value of 69 mi. per degree of latitude:

Example: Approximate the distance between point A at 30° north latitude, 110° east longitude, and point B at 42° north latitude,

Figure 6-7. Finding the distance between point A at 30° north latitude, 110° east longitude, and point B at 42° north latitude, 110° east longitude.



110° east longitude, as shown in Figure 6-7. The points have the same longitude, so they are on the same meridian. First, determine the number of degrees of latitude between the points:

$$42^{\circ} - 30^{\circ} = 12^{\circ}$$

Now, multiply the number of degrees of latitude between the points by the length of a degree of latitude:

$$12^{\circ} \times 69 \text{ mi.} = 828 \text{ mi.}$$

Example: Approximate the distance between point A at 22° south latitude, 65° west longitude, and point B at 22° south latitude, 79° west longitude, as shown in Figure 6-8. The points have the same latitude, so they lie on the same parallel. First, determine the number of degrees of longitude between the points:

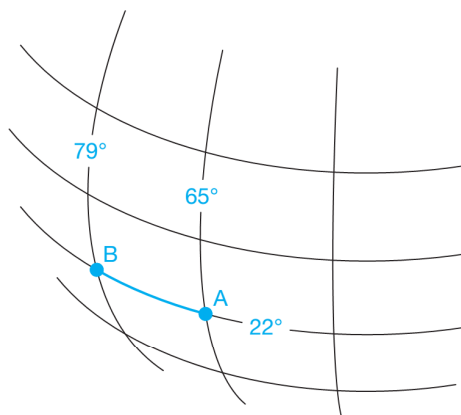
$$79^{\circ} - 65^{\circ} = 14^{\circ}$$

Next, calculate the length of a degree of longitude at 22° latitude, as previously described:

$$69 \text{ mi.} \times \cos 22^{\circ} =$$

$$69 \times 0.92718 = 64 \text{ mi.}$$

Figure 6-8. Finding the distance between point A at 22° south latitude, 65° west longitude, and point B at 22° south latitude, 79° west longitude.



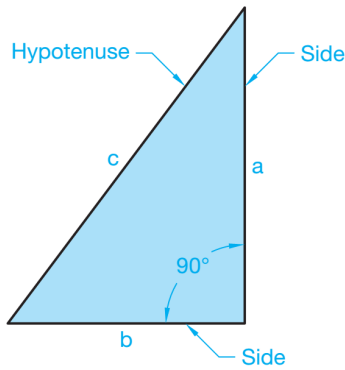


Figure 6-9. The hypotenuse is the longest side of a right triangle, opposite the 90° angle. A right triangle has one 90° angle.

Now, multiply the number of degrees of longitude between the points by the length of a degree of longitude at 22° latitude:

$$14^\circ \times 64 \text{ mi.} = 896 \text{ mi.}$$

Distances Between Locations on Different Parallels and Meridians If points are fairly close, such as a few hundred miles or less from each other on a different latitude and longitude, you can imagine the surface of the Earth as being flat and use the Pythagorean theorem to approximate distance. The Pythagorean theorem states the following, as shown in Figure 6-9:

- In a right triangle, the square of the length of the hypotenuse is equal to the sum of the squares of the lengths of the sides.
- The formula $a^2 + b^2 = c^2$, where a and b are sides of the right triangle, and c is the hypotenuse.
- The hypotenuse is the longest side of a right triangle, opposite the 90° angle.
- A right triangle has one 90° angle.

Example: Apply the following steps using the approximate value of 69 mi. per degree of latitude to estimate the distance between point A at 45° north latitude, 15° west longitude, and point B at 40° north latitude, 30° west longitude, as shown in Figure 6-10:

1. Find the number of degrees of latitude from point A to the longitude where point B is found:

$$45^\circ - 40^\circ = 5^\circ.$$

2. Calculate the distance in the previous step:

$$5^\circ \times 69 \text{ mi.} = 345 \text{ mi.}$$

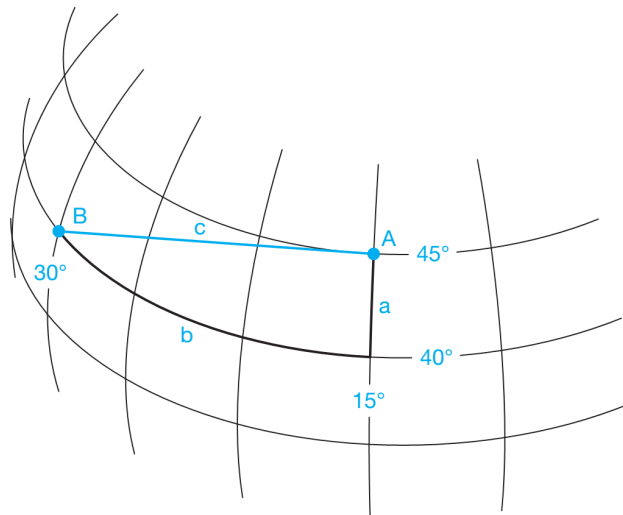


Figure 6-10. Using the Pythagorean theorem, $a^2 + b^2 = c^2$, to approximate the distance between fairly close points A and B, where a and b are sides of the right triangle and c is the hypotenuse, which is the distance between points A and B.

3. Determine the number of degrees of longitude from point B to the longitude where point A is located:

$$30^{\circ} - 15^{\circ} = 15^{\circ}.$$

4. Find the length of a degree of longitude at 40° latitude:

$$69 \text{ mi.} \times \cos 40^{\circ} = 69 \times 0.76604 = 52.857 \text{ mi.}$$

5. Establish the distance between 15° on 40° latitude:

$$15^{\circ} \times 52.857 \text{ mi.} = 792.86 \text{ mi.}$$

6. Use the Pythagorean theorem, $a^2 + b^2 = c^2$, to approximate the distance between points A and B, where a and b are sides of the right triangle and c is the hypotenuse, which is the distance between points A and B, as shown in Figure 6–10. From the previous calculations, $a = 345 \text{ mi.}$ and $b = 792.86 \text{ mi.}$ Continuing with the Pythagorean theorem:

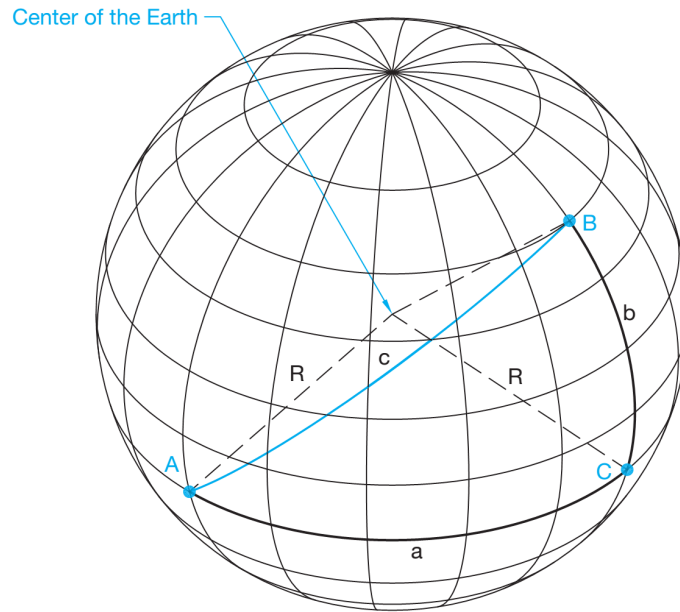
$$345^2 + 792.86^2 = c^2, 119,025 + 628,626.9796 = c^2, \\ c = \sqrt{747,651.9796}, c = 864.67 \text{ mi.}$$

Note: For ease and accuracy, use a calculator to make calculations. You can also search online for web-based calculators, such as a Pythagorean theorem calculator.

Far Distances Between Locations on Different Parallels and Meridians Generally, when points are a great distance away from each other, the shape of the Earth becomes an issue, and a spherical triangle must be solved in order to measure distance. A **spherical triangle** is a three-sided geometric object formed on the surface of a sphere by three great circular arcs intersecting at three vertices. **Great circular arcs** are arcs with their centers coinciding with the center of the sphere. A calculator or computer program is typically used to quickly and accurately solve a spherical triangle equation. The following provides a brief introduction to the spherical triangle.

A spherical triangle has angles A, B, and C, measured in radians at the vertices along the surface of the sphere. The sphere on which the spherical triangle sits has radius R. The Earth's mean radius is approximately 3,959 statute mi. (6,371 km). A **radian** is an angular unit of measure in which 2π radians = 360° and π radians = 180° . Figure 6–11 shows a spherical triangle on the Earth's surface. Notice how the sides a, b, and c of the spherical triangle are arcs rather than straight lines, as described when using the Pythagorean theorem and shown in Figure 6–10. The sum of the angles of a triangle with straight sides is equal to 180° , while the sum of the angles of a spherical triangle is 180° or greater. The amount by which the sum of the angles of a spherical triangle exceeds 180° is called the **spherical excess**. The spherical excess exists because the sides of the spherical triangle are arcs rather than straight line segments. The study of angles and distances on spherical surfaces is called **spherical trigonometry**.

Figure 6–11. A spherical triangle is shown on the Earth’s surface between points A, B, and C. Notice how the sides a, b, and c of the spherical triangle are arcs rather than straight lines, as described when using the Pythagorean theorem.



Map Projections and Coordinate Systems

The 3-D ellipsoidal shape of the Earth is projected onto a flat, 2-D plane such as a sheet of paper or computer screen, to create a map. The geometric methods of projecting the Earth’s surface onto a flat map are known as **map projections**. There are many different map projections based on different geometric principles and equations. The purpose of the map generally determines the selected projection. The Lambert conformal conic projection shown in Figure 6–12a, and the transverse Mercator projection shown in Figure 6–12b are two examples of common map projections.

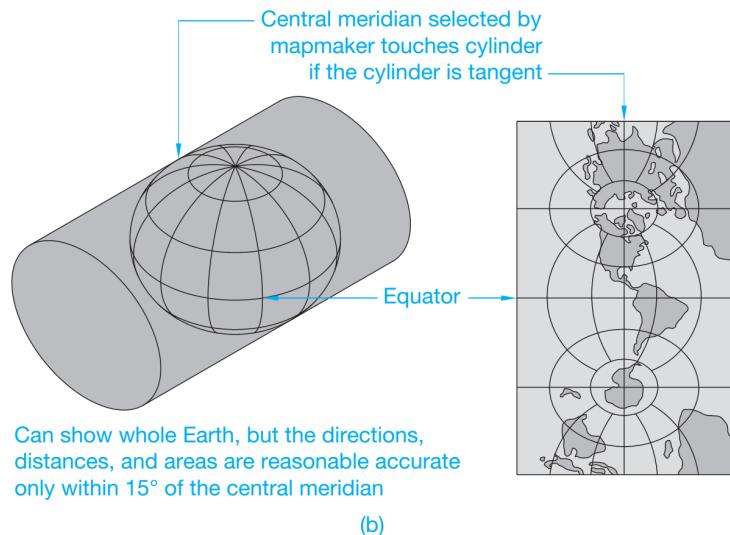
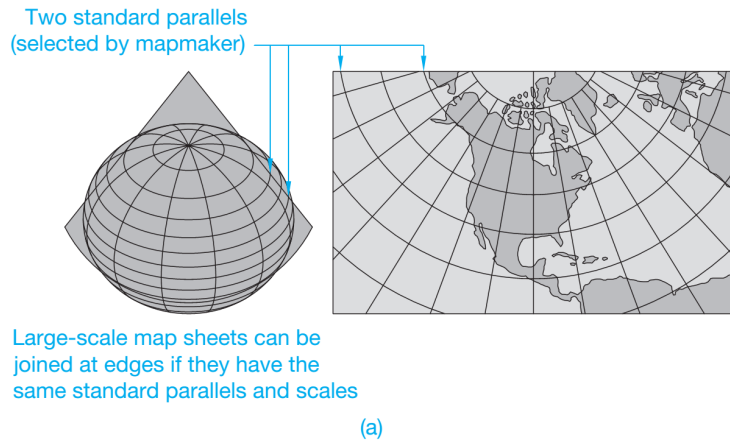
Map projections form the basis of map coordinate systems. A **map coordinate system** is a rectangular grid designed to simplify the creation and use of maps by specifying locations using *XY* coordinates. A rectangular grid avoids the need to locate points on curved latitude–longitude lines. The following information introduces the Universal Transverse Mercator (UTM) and State Plane Coordinate System (SPCS) coordinate systems used heavily in mapping, surveying, and civil engineering in the United States.

Universal Transverse Mercator (UTM)

The **Universal Transverse Mercator (UTM)** coordinate system is based on the Transverse Mercator map projection, and divides most of the world into 60, 6° longitude-wide zones between 84° north latitude and 80° south latitude (see Figure 6–13). UTM coordinates use an *XY* rectangular coordinate system with decimal-based measurements in meters (m). The UTM system allows a square grid coordinate numbering system to be tied directly to a distance measuring system.

Coordinates in each UTM zone are measured as easting (*X*) and northing (*Y*) values. Easting values (*X* coordinate) are measured from the central meridian that is halfway between the boundaries of

Figure 6-12. (a) The Lambert conformal conic map projection. (b) The transverse Mercator map projection.
(Data courtesy of the U.S. Geological Survey)

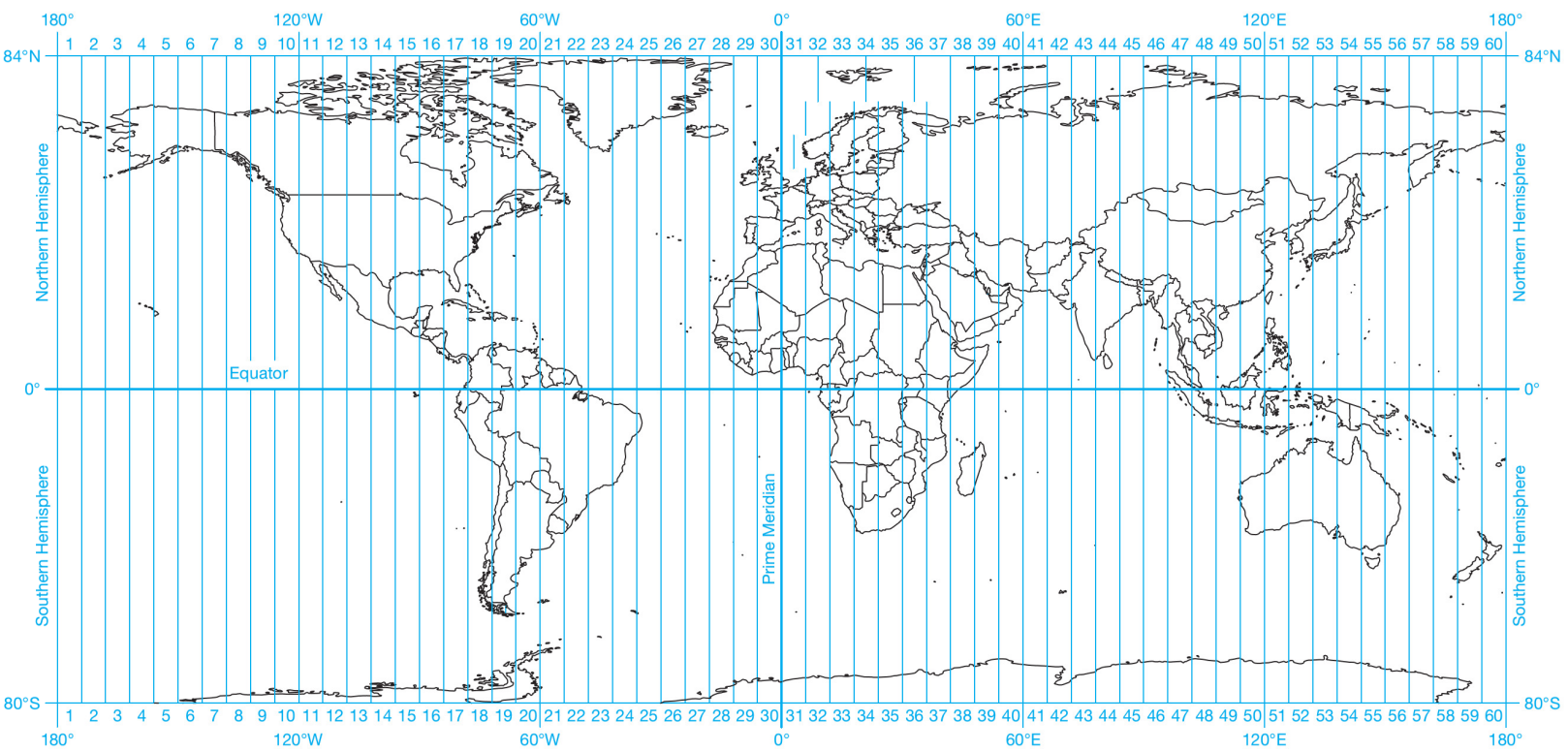


each zone. The central meridian in Zone 11, for example, is 117° west ($120^\circ - 3^\circ = 117^\circ$). The central meridian has an easting value of 500,000 m. A point 10,000 m east of the central meridian, for example, has an easting value of 510,000 m east (510,000mE). A point 10,000 m west of the central meridian has an easting value of 490,000 m east (490,000mE).

In the northern hemisphere, northing values (Y coordinate) are measured north from 0 m at the equator. For example, 1,500,000 m north (1,500,000mN) of the equator. In the southern hemisphere, northing values are measured from a false northing value of 10,000,000 m. A point 10,000 m south of the equator, for example, has a northing value of 990,000 m north (990,000mN).

When using the UTM system, locations are specified according to the easting/northing coordinates, such as 1,553,426mE, 1,963,704mN. Coordinates may also be shown as 1,553,426 1,963,704. The same easting/northing values can occur in different zones, and therefore, a map must identify the UTM zone, or coordinates can include the zone such as 1,553,426mE, 1,963,704mN, Zone 11. The same easting/northing values can also occur in the northern and southern hemisphere,

Figure 6-13. The Universal Transverse Mercator (UTM) coordinate system divides most of the world into 60, 6° longitude-wide zones. UTM zones are numbered from Zone 1 to Zone 60.



and therefore, a map must identify the hemisphere, or coordinates can include the hemisphere such as 1,553,426mE, 1,963,704mN, Zone 11, Northern Hemisphere. This example of a complete coordinate description can be abbreviated using 11 for Zone 11 and N for Northern Hemisphere, such as 11N 1,553,426 1,963,704.

State Plane Coordinate System (SPCS)

The **State Plane Coordinate System (SPCS or SPS)** is a series of separate U.S. state coordinate systems established by the U.S. Coast and Geodetic Survey (USC&GS) that is now the NGS. The SPCS for most states that are longer east–west, such as the State of Kansas, is based on the Lambert conformal conic projection. The SPCS for most states that are longer north–south, such as the State of Idaho, is based on the transverse Mercator projection. The SPCS for the panhandle of Alaska is based on the oblique Mercator map projection. Figure 6–14 shows each SPCS zone. The SPCS uses smaller zones than the UTM coordinate system, and therefore results in less distortion than the UTM system. The geographic coordinate system and SPCS are typically the most relevant coordinates systems for civil engineering and drafting in the U.S. Many civil engineering drawings originate from field survey data linked to the SPCS.

SPCS coordinates use an XY rectangular coordinate system with decimal-based measurements. The State Plane Coordinate System of 1927 (SPCS 27) is based on the North American Datum of 1927 (NAD 27) and uses the U.S. survey foot unit of measure. The **U.S. survey foot** is defined as 1,200/3,937 m, or 0.3048006096 m. The standard, or international, foot, often written as SI foot, is defined as exactly 0.3048 m. The State Plane Coordinate System of 1983 (SPCS 83) is based on the North American Datum of 1983 (NAD 83) with coordinates expressed usually in meters. SPCS units are in meters, U.S. survey feet, or international feet depending on the state. SPCS zones typically follow U.S. land survey and county boundaries, except in Alaska. Each zone is specified by a NGS code number. Figure 6–15 shows the State of Alabama SPCS that is divided into west (Zone 0102) and east (Zone 0101) zones. A complete SPCS definition includes the state, zone, zone code, map projection, central meridian when applicable, scale factor reduction at the central meridian when applicable, latitude and longitude of the origin, and false easting and northing values.

Coordinates in each SPCS zone are measured as easting (X) and northing (Y) values. The origin of each SPCS zone is located in the zone but is assigned false easting and/or false northing values as necessary to allow all coordinates within the zone to be positive. The X axis is an established distance west of the zone’s central meridian, and the Y axis is a distance south of the zone’s furthest point south. The central meridian of a zone occurs roughly through the center of the zone. Easting values (X coordinate) are measured from the false easting central meridian. For example, a point 20,000’ west of a 500,000’ central meridian has an easting value of 480,000’ east (480,000ftE). Northing values (Y coordinate) are measured north from the false northing parallel. For example, a point 50,000’ north of a 0’ parallel has a northing value 50,000’ north (500,00ftN). The coordinates of this point are 480,000ftE, 50,000ftN.

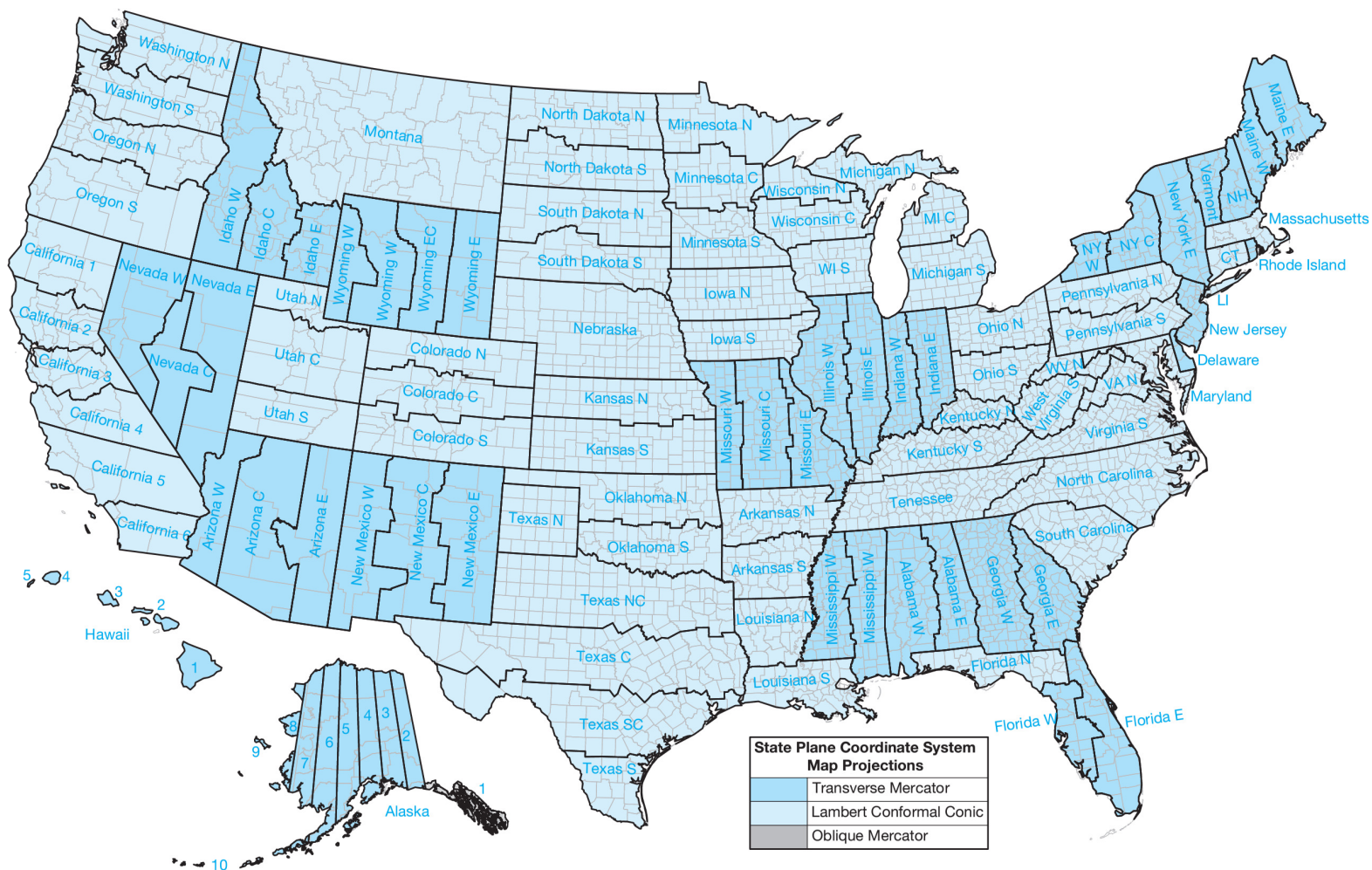


Figure 6-14. The State Plane Coordinate System (SPCS) divides the United States into separate coordinates systems, each covering a state or a portion of a state.

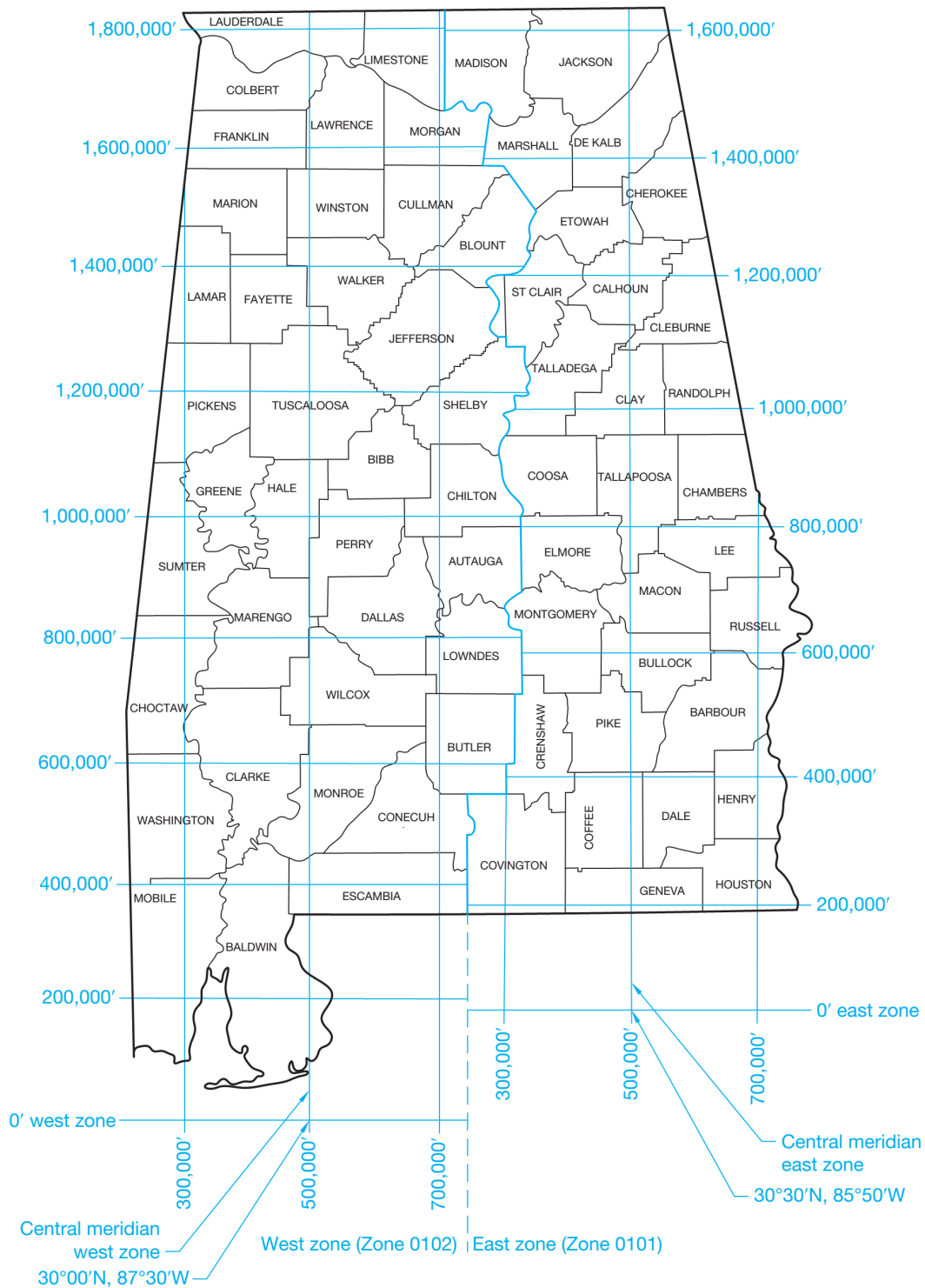


Figure 6–15. The State of Alabama SPCS is divided into west (Zone 0102) and east (Zone 0101) zones.

Locations on Quadrangle Maps

A **quadrangle map** is a map of an area of the Earth's surface with a grid showing geographic location. Figure 6–16 displays an example of a **US Topo** quadrangle map created by the U.S. Geological Survey (USGS). The USGS publishes quadrangle maps at different sizes, and with other information such as aerial imagery, on layers. The 7.5-minute quadrangle map shown in Figure 6–16 is common. A 7.5-minute quadrangle map displays 7.5 minutes of latitude and 7.5 minutes of longitude, and is drawn at a 1:24,000 scale. The **margin**, or **collar**, is the area around the body of a quadrangle map that displays information about the map such as the title, scale, location references, map projection, and coordinate system.

The block of text labeled A in Figure 6–16 is known as the credit legend. The **credit legend** provides a variety of information about the mapping and geodetic control agencies, and how the map was created. The map datum for XY coordinates is specified using the NAD 83, which is nearly identical to the WGS 84 datum. The UTM zone is identified as Zone 16, which extends 90° to 84° west longitude. The map is located in the Tennessee zone of the SPCS and uses SPCS 83 specifications. The information to the right of the credit legend, labeled B, specifies true north (TN), magnetic north (MN), and grid north (GN). You will learn more about direction and north in Chapter 7.

Note C in Figure 6–16 identifies a latitude of 36°07'30"N at the corner of the map. Minutes, and seconds when appropriate, of latitude are shown at 2.5-minute intervals as labeled by D. The tick mark and 10' value at D indicates a latitude of 36°10'00"N. A **tick mark** is a small vertical or horizontal line segment on the margin. Note E identifies the longitude of 86°52'30"W at the corner of the map. Minutes, and seconds when appropriate, of longitude are shown at 2.5-minute intervals as labeled by F. The tick mark and 47'30" value at F specify a longitude of 86°47'30"W. Geographic coordinates are shown at all sides and corners of the map.

Note G in Figure 6–16 points to a tick mark and UTM easting value. The mark and 513 value at G indicates 513,000 m (513,000mE), which is 13,000 m E of the 500,000 m Zone 16 central meridian. Note H points to a tick mark and UTM northing value. The mark and 3999 value at H indicates 3,999,000 m N of the equator. The UTM grid is shown in groups of 1,000 m (1 km).

Note I in Figure 6–16 points to a tick mark and SPCS easting value. The tick mark and 1 720 000 FEET value at I indicates 1,720,000' east (1,720,000ftE) of the origin of the Tennessee SPCS zone. Note J points to a tick mark and SPCS northing value. The tick mark is 670,000' north (670,000ftN) of the origin of the Tennessee SPCS zone.

Horizontal Distances

Measuring the horizontal distance between two points is a fundamental surveying and civil engineering design and construction process. The length of a property line, distance between structures, and width of a

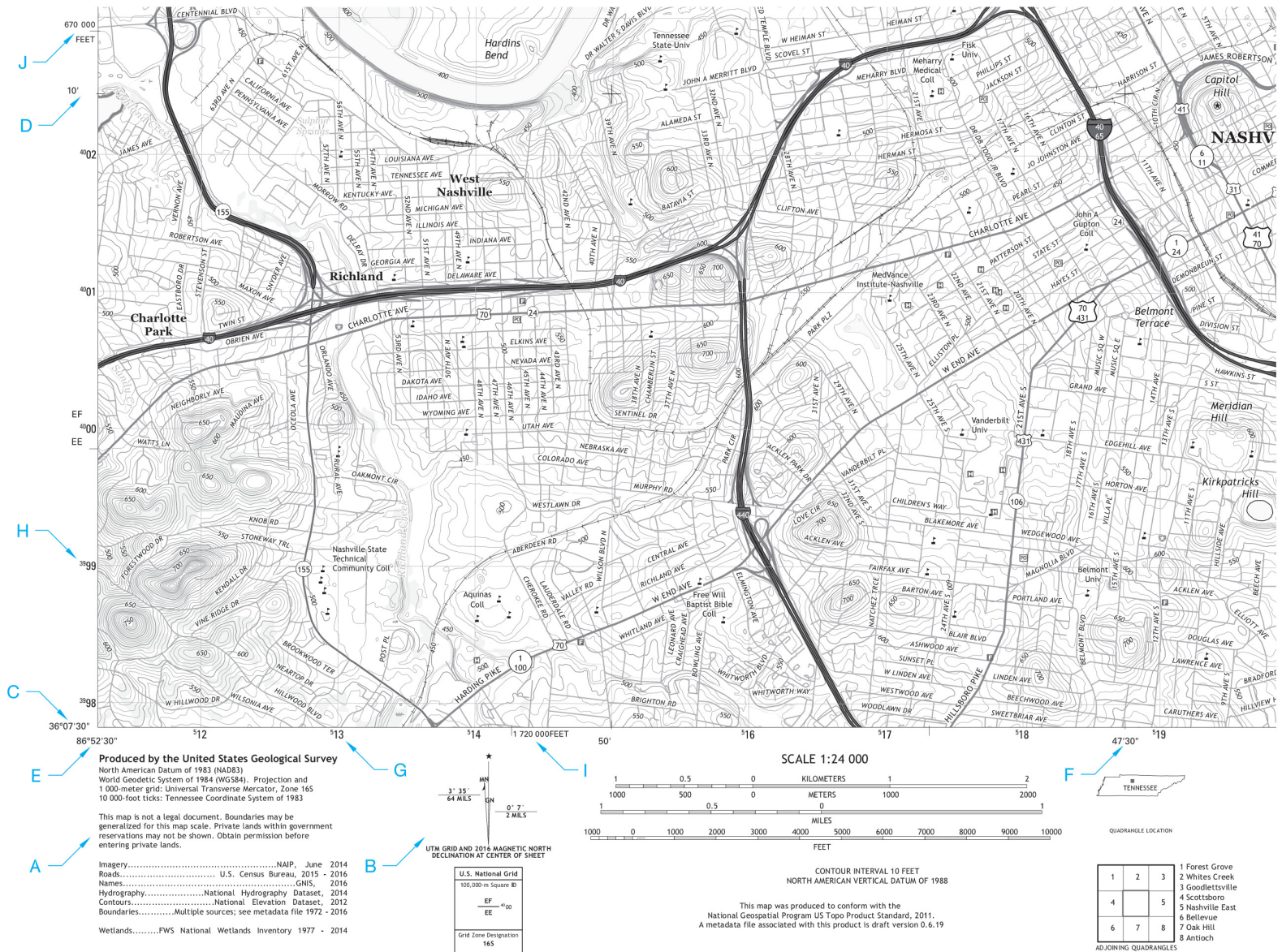


Figure 6-16. A portion of the Nashville West, Tennessee quadrangle map.
 (Map courtesy of the U.S. Geological Survey)



Figure 6-17. A single reflector uses a corner cube prism to reflect a laser beam back to the EDM device.

(Courtesy of Topcon)



Figure 6-18. A handheld EDM device uses a laser beam reflected off of an object, such as a wall or curb, to measure distance.

(Courtesy of Trimble)

road are basic examples of horizontal measurements. Surveyors use a variety of methods to measure horizontal distances depending on project requirements. As explained in Chapter 5, drawings for civil engineering projects are created from data obtained using survey instruments such as total stations and global navigation satellite systems (GNSSs), aerial photography, and in some cases 3-D laser scanners. The following information introduces methods of measuring horizontal distances.

Electronic Distance Measurement (EDM)

Surveyors use electronic distance measurement (EDM) and GNSS to measure distances whenever possible. Chapter 5 explains GNSS. An EDM device, also known by other terms such as **electronic distance measuring instrument (EDMI)** and **electronic distance meter (EDM)**, is a device that measures distance using electromagnetic or microwave radio waves, or infrared or laser light waves. Current EDM devices primarily use infrared and laser technology. An EDM device transmits light waves to a reflector or surface, which reflects the light back to the transmitting instrument. The time required for the signal to return to the device is measured and translated into a distance. A second approach uses the laser wavelength and phase shift of the reflected beam to determine distance. Both approaches are common and produce similar precision. Distances are recorded and stored onboard the instrument or in a separate device. Distances can be measured on a level line of sight or on a slope.

Lasers in EDM devices can be used to measure distances between the surveying instrument and a prism or prism array mounted on a tripod (see Figure 6-17). Greater distances may require larger prism arrays. A single reflector uses what is called a **corner cube prism**, which is a corner cut off of a cube of glass. A corner cube prism reflects the beam of light back onto the incoming path. It can be slightly out of alignment with the EDM device and still provide an accurate measurement. The total station, introduced in Chapter 5, is a tripod-mounted instrument that contains an EDM device. Horizontal and vertical angles between the total station and the measured points, when combined with a distance measurement, can provide location and elevation (XYZ) data for any point.

Some laser EDMs can also operate in reflectorless mode, in which a prism is not required to measure the distance. The laser beam can be aimed at an object, such as a wall, curb, or street intersection, and the distance is measured. Reflectorless EDM technology in total stations is generally accurate for distances less than 0.75 mi. (1,200 m). Figure 6-18 shows a handheld EDM that uses a laser beam reflected off of objects to measure distances such as measuring buildings for construction projects.

Traditional Methods of Measuring Distances

Even with the advent and refinement of EDM and GNSS, traditional methods of measuring distance, such as pacing and taping, continue to be useful for some purposes and serve as a valuable reference.

Pacing is a way to measure distance by walking and counting the

number of steps taken. Pacing is inaccurate compared to other forms of distance measurement, but is useful for quickly taking rough measurements without using equipment. A pedometer can be used to pace long distances, general over 200'. A **pedometer** is an instrument that estimates the distance traveled by walking and records the number of steps taken.

The **measuring wheel** shown in Figure 6–19 is a device that measures and records distance as a wheel is rolled along the ground. An **odometer**, much like the device that records the distance you travel in your vehicle, is similar to a measuring wheel and is also used to measure and record distance. Measuring wheels and odometers offer accuracy similar to or slightly better than pacing, and are generally used to take rough measurements over long distances.

Taping is the process of using a tape measure, or tape, to measure distances. Taping is a slower process than using EDM and GNSS, especially over longer distances or on steep slopes. Taping is therefore most often used to measure distances less than 100' (30 m) such as measuring buildings and staking out small construction sites. Figure 6–20a shows an example of a steel tape. There are many different types of tapes for different applications. A 100' long steel tape graduated in feet and hundredths of feet is common. A 30 m long steel tape graduated in meters and millimeters is a common metric tape. Fiberglass, or woven, tapes such as the example shown in Figure 6–20b are generally less expensive and stronger than steel tapes and come in a variety of lengths. Taping is also known as **chaining**, which is a term leftover from the use of the old 66' long Gunter chain.



Figure 6–19. Measuring distance using a measuring wheel.
(Kara/Fotolia)

Figure 6–21a shows how taping is used to measure distances. Hubs or markers of some sort are placed at each point where a reading is to be made. A **plumb bob** is a weight hanging from a string used to establish a vertical line to a point. Additional equipment used for taping include range poles for sighting points and guiding tapersmen, taping pins for marking locations on the tape, hand levels to help establish a horizontal tape, and tools to apply tension to the tape. When tape measurements must be made on a slope, the process is often referred to as **breaking chain** (see Figure 6–21b).

Note: There are other obsolete or seldom used methods of measuring distances. **Stadia** is an example of distance measurement once used to take rough measurements and to check more precise surveys. **Stadia** refers to a type of distance measuring that uses a survey rod and crosshairs in the reticle of optical instruments.

Vertical Distances

Elevation is the height of a geographic location above or below a theoretically exact reference point, axis, or plane. A **vertical datum** provides the zero elevation reference for elevations of surfaces and features on the Earth. A geodetic vertical datum is the principal datum used to express land elevations and to provide vertical survey control. The current vertical datum in the U.S. is the North American Vertical Datum of 1988 (NAVD 88). NAVD 88 is a geodetic vertical datum maintained by the NGS. U.S. territories have their own vertical datums, and a new vertical datum is in development for the State of Hawaii. NGS vertical datums are an element of the National Spatial Reference System (NSRS).

The reference datum used for a survey may be any solid object with a known elevation from the vertical datum, such as a bench mark (BM) or a temporary control point established by a surveyor.



Figure 6–20. (a) A steel tape used to measure distance. (b) A fiberglass, or woven, tape used to measure distance.

(Figure (a) Inzyx/Fotolia, figure (b) phirakon jaisangat/Fotolia)

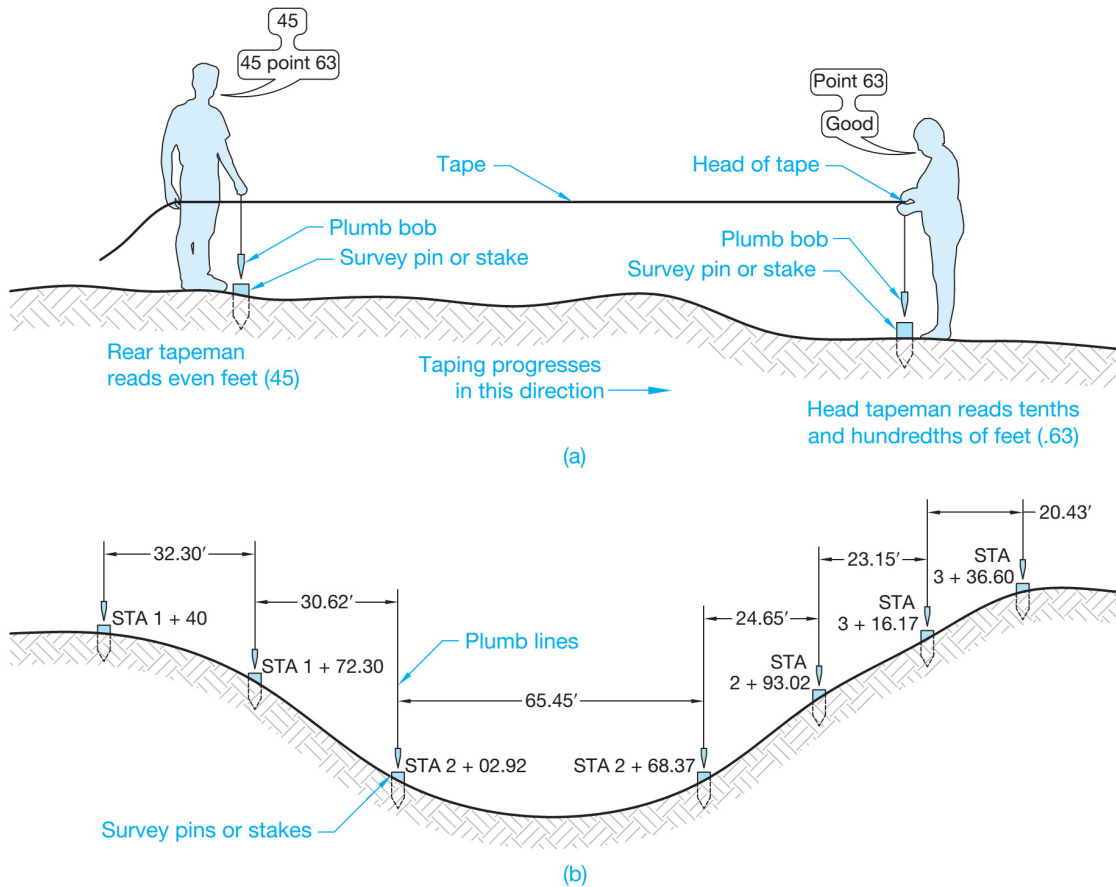


Figure 6-21. (a) The basic concept of taping, or chaining, to measure a horizontal distance of 45.63'. (b) The concept of breaking chain on sloping terrain. The tape must be horizontal for each measurement.

A **BM** is a survey mark intended to be permanent, that specifies the latitude, longitude, and elevation of a point. Measuring the elevation of points is an essential surveying and civil engineering design and construction process. The existing and finished elevations of a building site, depth of an underground utility line, and height of roadway features such as curbs are basic examples of elevation measurements. Surveyors use a variety of methods to measure vertical distances depending on project requirements. The following section provides valuable information about the process of determining elevation by differential leveling and gives you important background knowledge.

Note: Geodetic vertical datums such as NAVD 88 are the principal vertical datums used to measure the elevation of land features. Water level, or tidal, vertical datums such as mean sea level, were used prior to NAVD 88. **Mean sea level (MSL)** is the average of high and low tides taken by a tide gage over an extended period of time. Geodetic vertical datums provide elevation data relative to a reference surface related to MSL and may have a datum point at a tide gage.

Leveling

Leveling is the process of determining the difference in elevations between points. There are different systems of leveling. **Direct leveling**, also known as **spirit leveling**, is the theory of measuring vertical distances relative to a horizontal line, and using the measurements to calculate the differences between the elevations of points. Direct leveling is the most common system of leveling associated with surveying and civil engineering. The term **differential leveling** refers to the method used to determine the difference in elevation between two points. Differential leveling begins at a point of known elevation and works toward points with unknown elevations.

Field work and preliminary site work often require approximations before accurate leveling or surveying can begin. Rough leveling estimates can be accomplished with the use of a hand level (see Figure 6–22). A hand level is also used in taping to help establish a horizontal tape. Accurate differential leveling is normally performed using a level mounted on a tripod, and a level rod. A **surveyor's level** is an instrument with a telescope and spirit level or compensator used to establish a horizontal line for measuring elevations. A **level rod**, also known as a **level pole** or **level staff**, is a rod graduated to fractions of feet or meters used to measure elevations and distances when viewed through a level or transit.

Figure 6–23a shows an example of an automatic level. An automatic level maintains a horizontal line of sight once leveled. The digital level shown in Figure 6–23b includes a graphical display that provides a readout of elevations. Field measurements can be stored in a digital level's internal memory or transferred to a USB storage device or field computer. The data files can in turn be transferred to an office computer. Figure 6–23c shows a tripod on which a level is mounted. Figure 6–24 shows examples of level rods. A footplate used with some level rods provides a stable, well-defined foundation for the rod. A **footplate** is a cone-shaped device that has pointed feet anchored in the ground.

Leveling Process

Leveling begins by anchoring the tripod firmly in the ground at a location approximately halfway to the point with an unknown elevation to be measured. The instrument is attached to the tripod and leveled with three leveling screws on the base of the instrument. A spirit bubble and/or electronic display indicates when the instrument is level. The rod is then placed on a point with a known elevation. Accurate recording of elevations must begin at known elevation points. A survey mark, or monument (MON), described in Chapter 5, such as the



Figure 6–22. Hand levels are used to obtain approximate elevations and to help establish a horizontal tape when taping.
(Courtesy of Trimble)

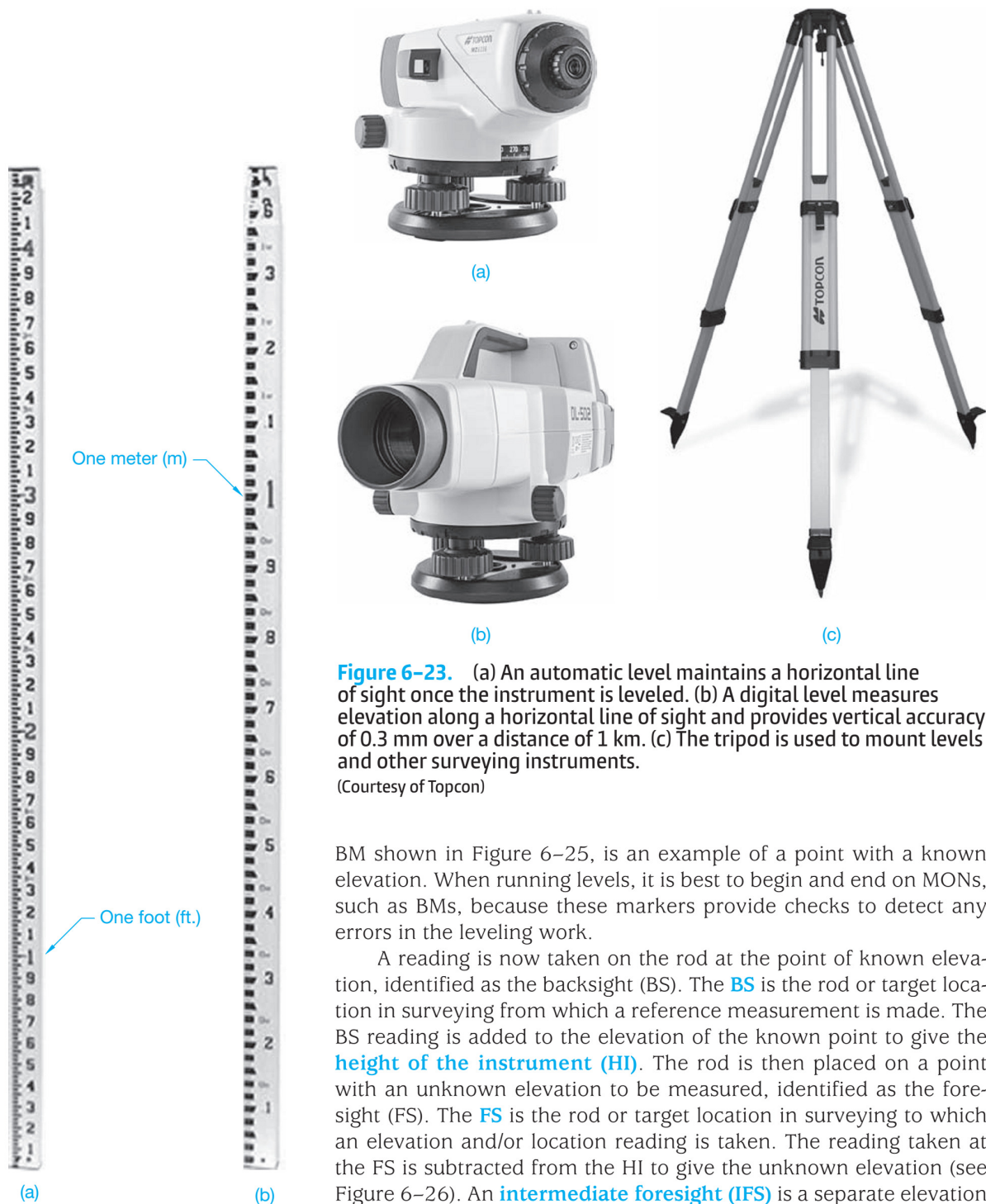


Figure 6-23. (a) An automatic level maintains a horizontal line of sight once the instrument is leveled. (b) A digital level measures elevation along a horizontal line of sight and provides vertical accuracy of 0.3 mm over a distance of 1 km. (c) The tripod is used to mount levels and other surveying instruments.

(Courtesy of Topcon)

BM shown in Figure 6-25, is an example of a point with a known elevation. When running levels, it is best to begin and end on MONs, such as BMs, because these markers provide checks to detect any errors in the leveling work.

A reading is now taken on the rod at the point of known elevation, identified as the backsight (BS). The **BS** is the rod or target location in surveying from which a reference measurement is made. The BS reading is added to the elevation of the known point to give the **height of the instrument (HI)**. The rod is then placed on a point with an unknown elevation to be measured, identified as the foresight (FS). The **FS** is the rod or target location in surveying to which an elevation and/or location reading is taken. The reading taken at the FS is subtracted from the HI to give the unknown elevation (see Figure 6-26). An **intermediate foresight (IFS)** is a separate elevation taken in addition to the run of levels for information purposes.

Surveyors often establish semi-permanent points, referred to generically as **local control points**. Local control points are called **temporary bench marks (TBMs)** because they are temporary, but serve the same purpose as a BM. The most temporary TBM, known as a turning point (TP), is used when level measurements must be

Figure 6-24. Telescoping fiberglass level rods. (a) A U.S. customary unit (foot) level rod. (b) A metric unit (meter) level rod.

(Courtesy of Trimble)



Figure 6-25. A benchmark (BM) survey mark set during a geodetic survey.
(Courtesy of Trimble)

made over long distances or large changes in elevation. A **TP** is a TBM such as a large rock, fire hydrant (FH), concrete curb or foundation, wooden stake, or metal spike, on which the rod is rested and used as a pivot for the rod. The TP acts as both a BS and an FS. An FS measurement to a TP is often taken using the top of an object (TO) such as an FH or curb as the TP. Once the TP elevation is determined, the instrument is physically moved to the next station point (STA). The rod is then physically turned to face the instrument. The instrument reading as an FS is subtracted from the HI to find the level of the TBM, and then the instrument and tripod are physically moved ahead of the rod and reset. The next reading to the TP is a BS, which is added to the TBM elevation to become the HI. Now the rod can be moved to the next FS position. Figure 6-27 illustrates leveling with several TPs required to measure elevations over long distances.

Leveling Example

For a better understanding of the leveling calculation process, take a few moments to work through the example shown in Figure 6-27. Before beginning this exercise, remember the basic rule for calculating elevation when running levels: add the BS and subtract the FS. In this example, the beginning point elevation of the BM is 462.65'. The level rod is placed on the BM. The level instrument is set up an appropriate distance away, in the direction of the unknown elevation. The rod reading of 3.90' is taken at the BS. The BS reading of 3.9' is added to the BM elevation of 462.65' to get the HI of 466.55'.

Now that the HI is known, the rod can be moved ahead to the next location, which is determined by terrain and distance. This rod location becomes TP 1. The rod is physically placed on a stable object and is not moved again until both FS and BS readings are made. The instrument reading is taken on the FS. In this case, the level rod reading is 10.85', which is subtracted from the HI of 466.55' to get the TP 1 elevation of 455.70'.

The instrument can now be moved to the next location, and the process is repeated. Notice in Figure 6-27 that the second position

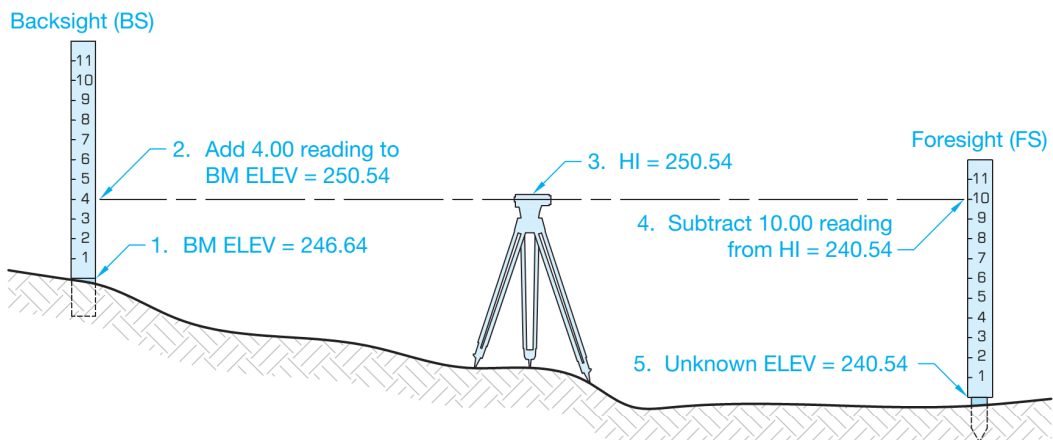


Figure 6-26. Using differential leveling to find an elevation with a level and rod.

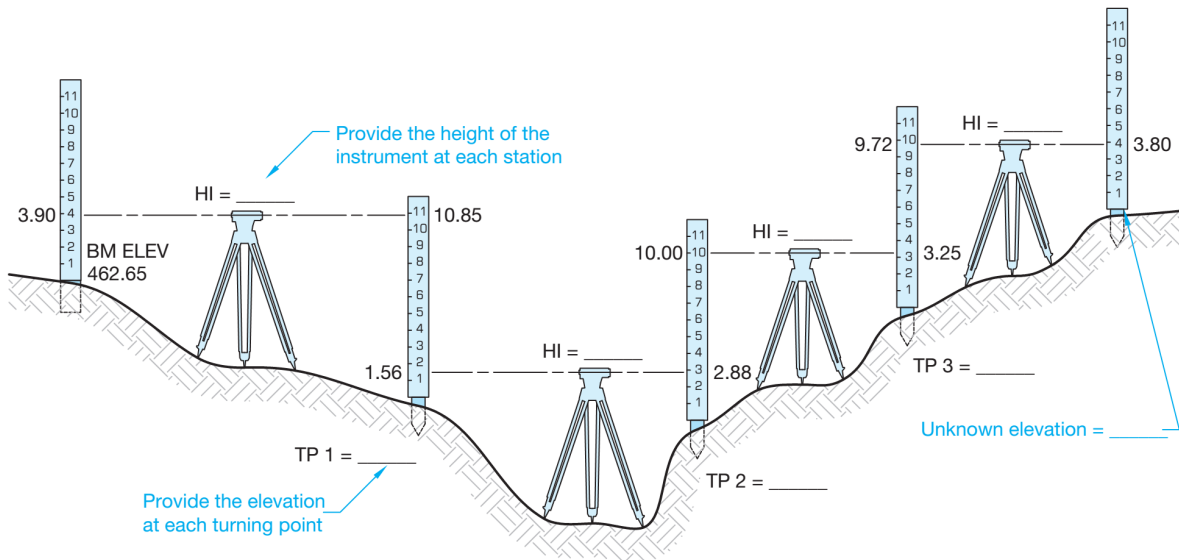


Figure 6-27. Using turning points to find an unknown elevation. The unknown elevation should equal 467.05'.

of the instrument in the valley is the same situation as the first instrument setup. Therefore, the next reading to be taken, the BS, is read and calculated the same as the first calculation in this exercise. The rod reading of 1.56' is taken at the BS. The BS reading of 1.56' is added to the TP 1 elevation of 455.70' to get the HI of 457.26'.

The rod is moved ahead to TP 2, and an FS reading of 2.88' is taken. The FS reading of 2.88' is subtracted from the HI of 457.26' to get the TP 2 elevation. Complete this exercise as described above to determine the unknown elevation.

Reading a Level Rod

A typical U.S. customary (foot) level rod is divided into whole ft., tenths, and one-hundredths of a ft. (see Figure 6-28). Metric (meter) level rods are also available. The whole ft. values on the level rod are shown in large red numerals. The large black numerals indicate tenths of a ft. and are located at a pointed black band on the rod. Each black band is one-hundredth of a ft. wide. Notice the small numbers located every three-tenths of a ft. on the rod face. These small red numbers indicate the whole ft. value and are references in case the view through the instrument shows only a small portion of the rod, and no large red number is visible.

Note: Rods that can be read by the person operating the instrument are called **self-reading rods**. A rod with a target vernier is often used to measure readings over distances longer than 200 to 300' (60 to 90 m). Once the rodperson precisely locates the vernier as directed by the person running the instrument, the rodperson reads the graduations on the vernier and records the elevation. The vernier on the target allows measurements of 0.001'.

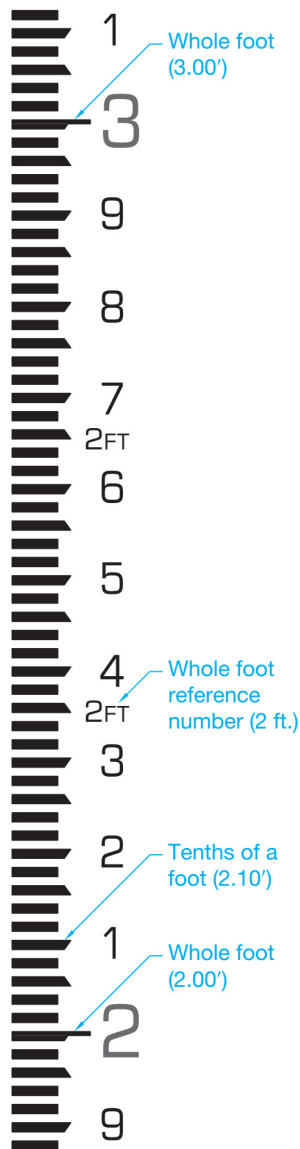


Figure 6–28. A close-up of a U.S. customary unit (foot) level rod divided into whole ft. and one-hundredths of a ft.

Precision Leveling

A digital level can be used to measure elevations and distances electronically when used with a special rod. The face of the rod is graduated with a bar code (see Figure 6–29). The reverse side of the digital rod contains standard numerical increments. The level captures the image of the bar code and compares it with the programmed image of the entire rod, which is stored in memory. The comparison of the captured image and the programmed image enables the height and distance to be calculated. These readings can be stored in memory or transferred to another location for processing.

An **optical-micrometer level** employs a special lens that can be rotated to vertically deflect the incoming light ray from the line of sight. The level instrument can then subdivide the level rod graduations to achieve an accuracy of ± 0.02 of the level rod graduation. The highest order of leveling and surveying, called first order, can be achieved with optical-micrometer levels.

Leveling Field Data

Field data based on leveling contain location and elevation information. Figure 6–30 shows an example of leveling field notes and calculations. The left column contains the location of the rod. The BS reading is taken looking back toward the point of beginning. HI is the height of instrument calculated by adding the reading taken from the BS. IFS is the intermediate foresight, with one measurement taken at the top of a fire hydrant (TO FH). FS is the foresight taken and subtracted from the HI to give the elevation (ELEV) of the new TP, which is listed in the last column. The leveling process continues until the final elevation is determined.

The difference between the totals of the BSs and the totals of the FSs equals the difference in elevation between the BM and the final elevation. This value can be used to check for error in the intermediate calculations. Notice at the bottom of the right column that the difference between the BM and final elevation is calculated to be 12.86. The last row of the field notes, labeled Level check, shows the totals of the BS and FS columns. The difference between these two is also 12.86, which means there have been no errors in the intermediate calculations.

Construction Laser Levels

The electronic, or laser, level is commonly used for construction work such as leveling to set elevation grade stakes for road, parking lot, and driveway grades, and elevations for excavations, fills, concrete work, plumbing, and floor level verification. There are several different types of laser levels and accessories for specific applications. The **rotating beam laser level**, or **rotating laser level** shown in Figure 6–31 projects a 360° rotating laser beam in a plane. The beam appears on a surface as a line that can be detected anywhere around the instrument. Rotating lasers are used for a variety of purposes from basic surveying and site layout to establishing grades.

Figure 6–29. A digital level can be used to measure elevations and distances electronically when used with a special rod. The face of the rod is graduated with a bar code. The reverse side of the digital rod contains standard numerical increments.

(Courtesy of Trimble)



Digital Level



Digital Level Rod

A **pipe laser level** projects a laser beam in front of the instrument that appears on a surface as a dot. Pipe lasers are typically used to align pipe and are often mounted directly to pipes and features associated with pipelines. A **line laser level** projects a laser beam or beam in front of the instrument that appears on a surface as a line or crosshairs. Line lasers are used for applications such as leveling and plumbing floors, walls, and ceilings. A **plumb laser level** projects a beam in front of the instrument that appears on a surface as a dot. Plumb lasers are used for leveling and plumbing applications when a reference line is not necessary. Most laser levels can produce a laser beam or beams horizontally, vertically, or at a specified angle as needed. Laser beams can be effective to a radius of more than 2,600' (800 m). A **laser detector**, also known as a **laser receiver**, is used to detect the beam from a laser level when the beam cannot be seen, such as over far distances or in bright light.

Figure 6–30. Field notes for leveling contain measurements and elevation information.

Leveling Computation					
STA	BS(+)	HI	IFS(-)	FS(-)	ELEV
BM E635	4.62				735.62
		740.24			
TP 1	6.81			3.78	736.46
		743.27			
TP 2	1.04			11.36	731.91
		732.95			
TO FH			6.77		726.18
TO CURB				10.19	722.76
	BS total = 12.47			FS total = 25.33	735.62 - 722.76 <u>12.86</u>
				Level check	FS 25.33 - BS 12.47 <u>12.86</u>

Figure 6–31. A rotating laser level projects a 360° rotating beam as a plane for reference.
(Courtesy of Topcon)



CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Define the following terms.

6-1 Coordinate system

6-2 Oblate spheroid

6-3 Datum

6-4 Geocentric datum

6-5 Degree

6-6 Taping

6-7 Elevation

6-8 Bench mark (BM)

6-9 Leveling

6-10 Direct leveling

Part 2

Choose the response that best describes each statement.

- 6-11** The point on the Cartesian coordinate system where the X , Y , and Z axes intersect is called the:
- a. Intersection
 - b. Source
 - c. Origin
 - d. Alignment
- 6-12** The Cartesian coordinate location of 34,78 represents a point that is:
- a. 34 units from the origin in the X direction and 78 units from the origin in the Z direction
 - b. 34 units from the origin in the X direction and 78 units from the origin in the Y direction
 - c. 78 units from the origin in the X direction and 34 units from the origin in the Z direction
 - d. 78 units from the origin in the X direction and 34 units from the origin in the Y direction
- 6-13** Lines of latitude:
- a. Are measured as an linear distance from the point at the center of the Earth
 - b. Connect the north and south poles
 - c. Are called parallels
 - d. Are the exact same distance apart
- 6-14** What is the approximate length of a degree of latitude?
- a. 64 statute miles
 - b. 69 nautical miles
 - c. 69 statute miles
 - d. 690 statute miles
- 6-15** A statute mile equals:
- a. 528 ft.
 - b. 1,600 m
 - c. 5,280 ft.
 - d. 1.5 km

- 6-16** The line that represents 0° longitude is also called:
- a. The international date line
 - b. The prime meridian
 - c. The equator
 - d. Greenwich, England
- 6-17** Refer to Figure 6-16. What is the distance from Vanderbilt University to the equator?
- a. 4,000,000 m
 - b. 4,000,000 mi.
 - c. 517,500 m
 - d. 517,500 mi.
- 6-18** What is the length of a degree of longitude at 22° latitude?
- a. 69 statute miles
 - b. 65 statute miles
 - c. 64 statute miles
 - d. 62 statute miles
- 6-19** What is the Pythagorean theorem formula?
- a. $a^2 + b^2 = c^2$
 - b. $a^2 \times b^2 = c^2$
 - c. $a^2 + b^2 = c$
 - d. $a^2 \times b^2 = c$
- 6-20** What is the name of the longest side of a right triangle, opposite the 90° angle?
- a. Acute triangle
 - b. Leg
 - c. Side
 - d. Hypotenuse

Part 3

Calculate the approximate distance between the following points.

- 6-21** A point at 45° north latitude, 20° west longitude and a point 30° north latitude, 20° west longitude.

- 6-22** A point at 50° north latitude, 80° west longitude and a point at 50° north latitude, 20° west longitude.
- 6-23** A point at 10° north latitude, 80° west longitude and a point at 10° north latitude, 20° west longitude.
- 6-24** A point at 72° north latitude, 28° west longitude and a point at 18° north latitude, 28° west longitude and a point at 18° north latitude, 42° west longitude.
- 6-25** A point at 22° south latitude, 65° west longitude and point at 22° south latitude, 79° west longitude.

Part 4

Study the portion of the quadrangle map shown in Figure R6-1 to answer the following questions. The entire map is available for download and viewing. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Chapter 6 Map.pdf.

- 6-26** The map displays _____ of latitude _____ of longitude, and drawn as a _____ scale.
- 6-27** The credit legend identifies the map datum for XY coordinates as the _____ which is nearly identical to the _____ datum.
- 6-28** The map shows a portion of the State of _____ in the UTM zone _____. The SPCS is based on the _____.
- 6-29** The latitude at the lower-left corner of the map is _____ and the longitude at the corner of the map is _____.
- 6-30** Peregoy Meadow is approximately _____ north latitude.
- 6-31** The tick mark labeled 32'30" on the margin of the map identifies a longitude of _____ west.

- 6-32** Lost Bear Meadow is approximately _____ m false easting and _____ m north of the equator according to the UTM coordinate system.
- 6-33** A SPCS easting tick mark closest to the lower-left corner of the map identifies a point _____ east of the origin of the SPCS zone.
- 6-34** A SPCS northing tick mark closest to the lower-left corner of the map identifies a point _____ north of the origin of the SPCS zone.
- 6-35** The vertical datum used to establish elevations on the map is the _____.

PROBLEMS

Follow the specific instructions to complete each problem.

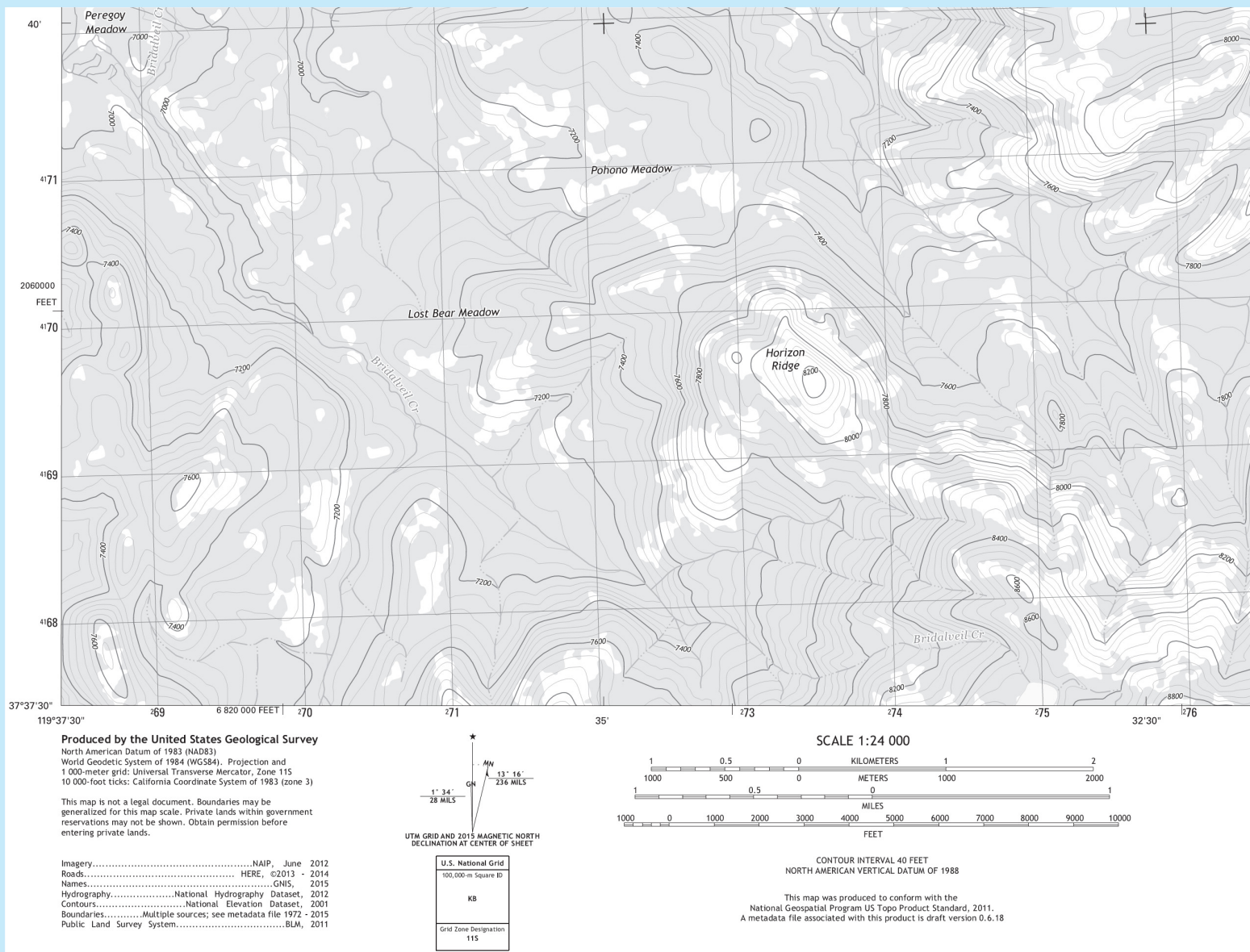


Figure R6-1 (Courtesy of the U.S. Geological Survey)

Part 1

Give the elevations indicated by the rod readings shown in Figure P6-1.

P6-1 See Figure P6-1.

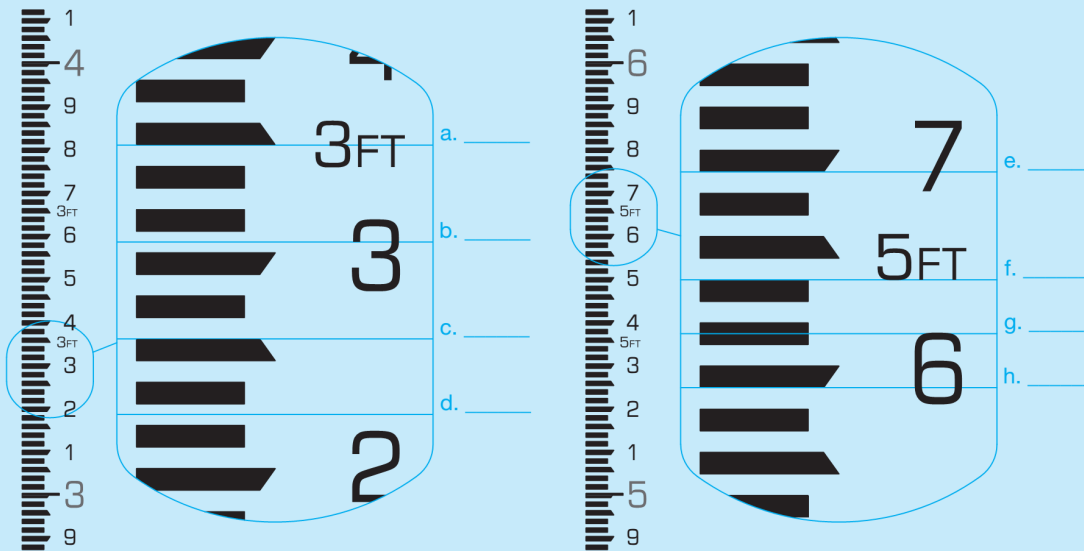


Figure P6-1.

Part 2

Calculate the unknown elevation given the specified leveling illustration.

P6-2 See Figure P6-2.

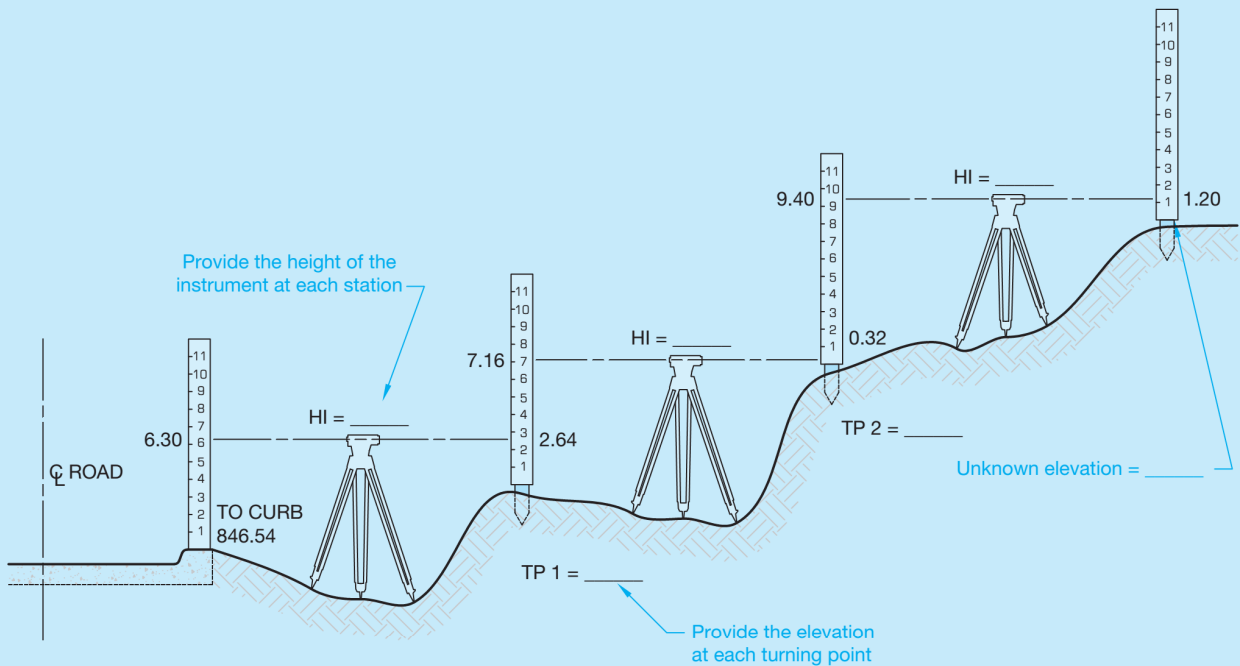


Figure P6-2.

P6-3 See Figure P6-3.

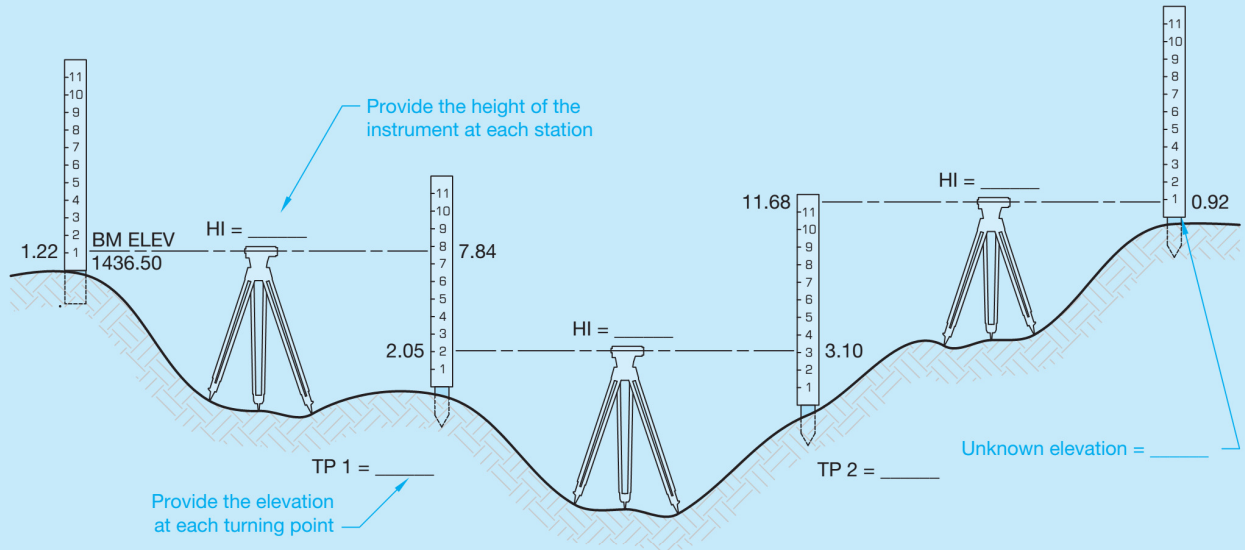


Figure P6-3.

Part 3

Complete the field notes from the given data. Check your final answer mathematically, as described in this chapter.

P6-4 See Figure P6-4.

STA	BS(+)	HI	FS(-)	ELEV
BM 1	6.21			422.34
TP 1	8.90		3.46	
TP 2	7.82		4.63	
TP 3	5.60		2.45	
BM 2	12.04		3.86	
TP 4	4.62		7.70	
TP 5	7.31		4.06	
BM 3			3.64	

Figure P6-4.

P6-5 See Figure P6-5.

STA	BS(+)	HI	FS(-)	ELEV
BM 1	3.63			247.4
TP 1	6.24		5.29	
TP 2	8.65		6.04	
TP 3	2.51		10.16	
BM 2			7.55	

Figure P6-5.

P6-6 See Figure P6-6.

STA	BS(+)	HI	FS(-)	ELEV
BM 1	8.21			946.85
TP 1	5.36		4.89	
TP 2	7.81		10.63	
TP 3	9.07		6.32	
TP 4	5.11		4.99	
BM 2			7.25	

Figure P6-6.

P6-7 See Figure P6-7.

STA	BS(+)	HI	FS(-)	ELEV
BM 1	6.992			946.85
TP 1	7.964		9.376	
TP 2	3.560		4.096	
TP 3	7.455		3.675	
TP 4	3.442		7.521	
TP 5	8.459		12.680	
TP 6	9.456		3.442	
TP 7	6.087		4.358	
BM 2			2.961	

Figure P6-7.

Part 4

Use the specified leveling illustration to create complete field notes with all necessary information and calculations. Provide a mathematical check of your work in the field notes.

P6-8 See Figure P6-8.

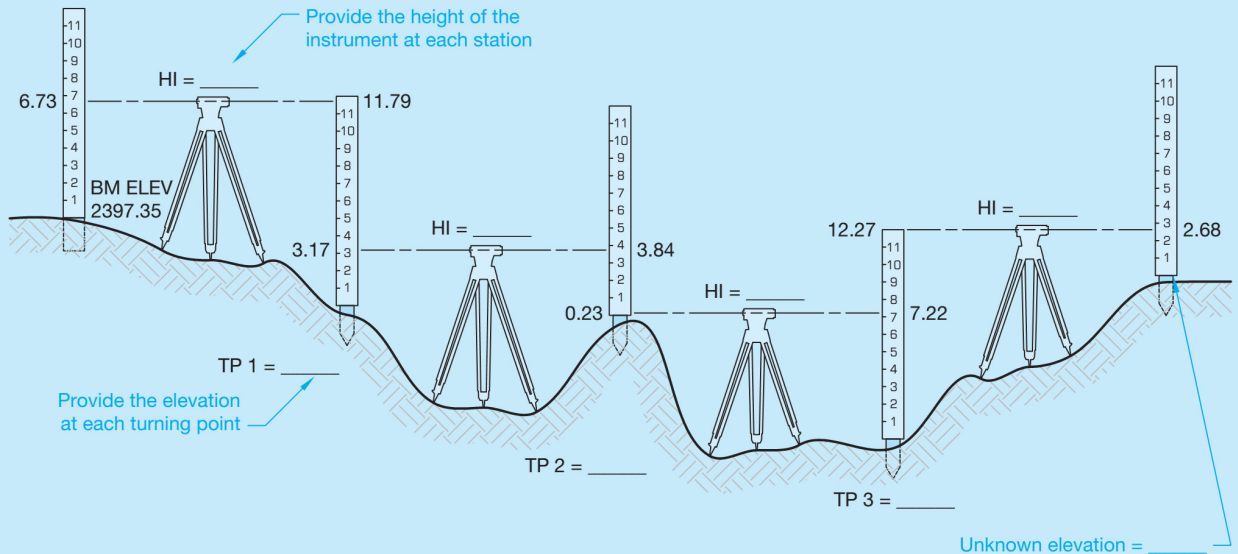


Figure P6-8.

P6-9 See Figure P6-9.

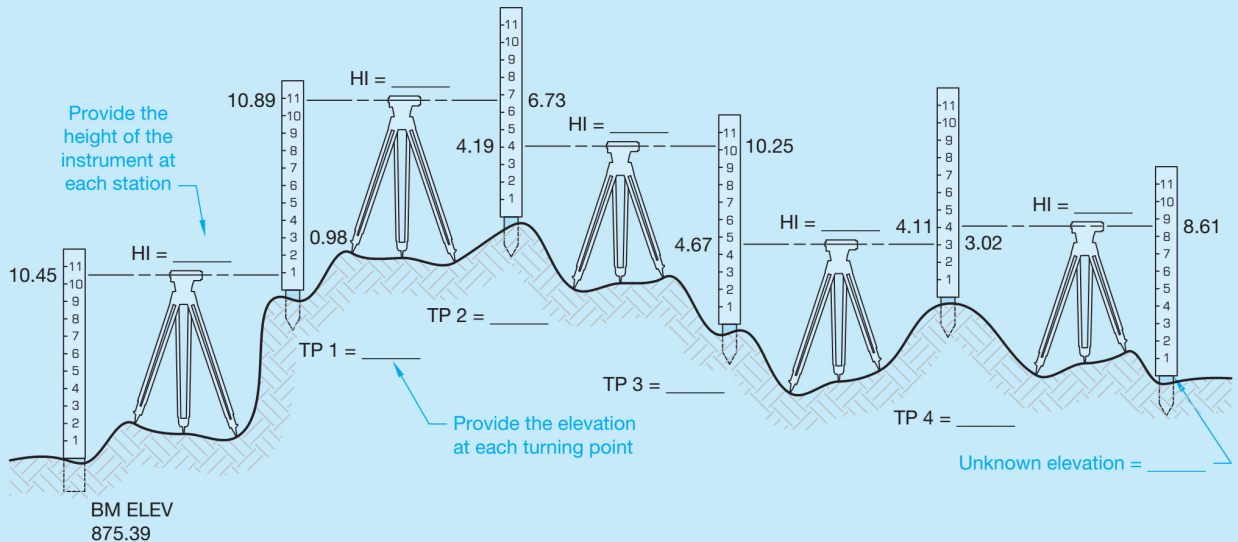


Figure P6-9.

Part 5

Use the plan view of the specified differential leveling operation to create complete field notes with all necessary information and calculations. Provide a mathematical check of your work in the field notes. The circles along the level line indicate instrument setups. The numbers are foresight and backsight readings from the instrument.

P6-10 See Figure P6-10.

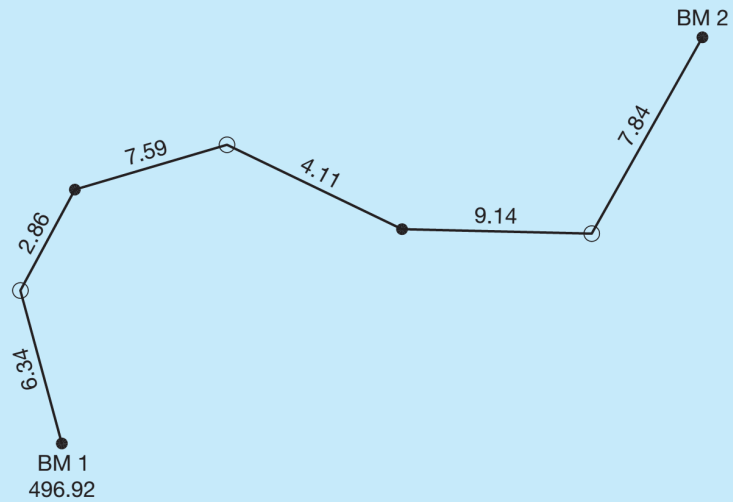


Figure P6-10.

P6-11 See Figure P6-11.

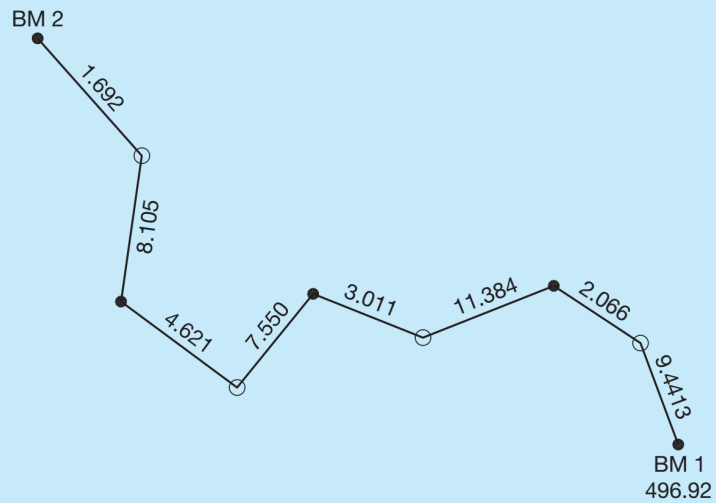


Figure P6-11.



CHAPTER

7

Angles and Directions

Learning Objectives

After completing this chapter, you will be able to:

- Identify and use units of angular measurement.
- Define terms associated with direction.
- Determine the azimuths and bearings of given lines.
- Establish the bearing, distance, cosine, sine, latitude, and departure from a given traverse.
- Draw traverses from given information.

Key Terms

Angle
Vertex
Direction
Radian
Milliradian
Mil
Degree
Sexagesimal system
Full angle
Straight angle
Reflex angle
Right angle
Perpendicular
Acute angle
Obtuse angle
Polygon
Regular polygon
Included angle
Meridian
True north (TN)
Geographic north
Geographic meridian
True meridian
Magnetic north (MN)
Magnetic compass
Magnetic meridian
Grid north (GN)
Magnetic declination (MD)
Azimuth
True azimuth (TA)
Magnetic azimuth

(continued)

Key Terms (*continued*)

Local attraction
Grid azimuth
Bearing
Traverse
Traverse stations
Station points
Open traverse

Closed traverse
Loop traverse
Connecting traverse
Deflection angle
Prolongation of the line
Plunged
Plot

Coordinate geometry (COGO)
Positive latitude
Negative latitude
Positive departure
Negative departures
Error of closure

An **angle** is the amount of space, or turn, between two lines, known as arms or sides, that intersect at a point known as the **vertex**. **Direction** is the angular relationship of one line to another. Measuring angles and directions are fundamental concepts associated with most civil engineering and civil drafting applications. This chapter explains angle and direction, and applies this information for traversing.

Angles

Intersecting property lines create a common example of an angle. There are several different units used to define angles. Degrees, radians, and milliradians are the most common units of angular measurement used in the United States. The following information focuses primarily on measuring angles using degrees. A **radian** is an angular unit of measure in which 2π radians = 360° and π radians = 180° . A **milliradian**, or **mil**, is a unit of angular measurement approximately equal to $1/6,400$ of the circumference of a circle.

Degrees Minutes Seconds

A **degree** is a unit of angular measurement. Degrees are identified with the degree ($^\circ$) symbol, such as in 50° . There are 360° in a complete circle, 270° in three-quarters of a circle, 180° in half of a circle, and 90° in a quarter of a circle. A degree is divided into fractions using the sexagesimal system. The **sexagesimal system** is a numerical system based on the division of 60. Each degree is made up of 60 minutes. Minutes are identified by the minutes ($'$) symbol, such as $30'$. Minutes are divided into 60 seconds. Seconds are identified by the seconds ($''$) symbol, such as $45''$. An example of a complete degrees minutes seconds designation is $50^\circ 30' 45''$. The National Geodetic Survey (NGS) uses the sexagesimal system to specify degrees.

Use the following examples to understand the process of adding and subtracting degrees minutes seconds angles. Addition example: $48^\circ 40' 25'' + 25^\circ 38' 40'' = 73^\circ 78' 65''$. In this case, the solution must be reduced because there are only 60' in a degree and 60'' in a minute: $73^\circ 78' 65'' = 73^\circ 79' 5'' = 74^\circ 19' 5''$. Subtraction example: $75^\circ 32' 10'' - 34^\circ 45' 8'' = 41^\circ - 13' 2''$. In this instance, you must borrow a degree from $75^\circ 32' 10''$ because you cannot specify negative minutes: $75^\circ 32' 10'' = 74^\circ 92' 10''$. Now you can complete the calculation: $74^\circ 92' 10'' - 34^\circ 45' 8'' = 40^\circ 47' 2''$.

Degrees Decimal Minutes and Decimal Degrees

Angular measurements in degrees can also be specified in degrees decimal minutes or decimal degrees. Degrees decimal minutes replaces the seconds of the degrees minutes seconds expression with a decimal fraction of a minute, such as $54^{\circ}2.5'$. To convert a degrees minutes seconds value to degrees decimal minutes, divide the specified number of seconds by the number of seconds in a minute, or 60. For example, to convert $27^{\circ}58'43''$ to degrees decimal minutes, calculate $43 \div 60 = 0.716667$. Therefore, the degrees decimal minutes equivalent is $27^{\circ}58.716667'$.

Decimal degrees replaces the minutes and seconds of the degrees minutes seconds expression with a decimal fraction of a degree, such as 54.041667° . To convert a degrees minutes seconds value to decimal degrees, divide the specified number of minutes by the number of minutes in a degree, or 60. Then, divide the specified number of seconds by the number of seconds in a degree, or 3,600. Finally, add the seconds together to find the fraction of the degree. For example, to convert $27^{\circ}58'43''$ to decimal degrees, calculate $58 \div 60 = 0.966667$ and $43 \div 3,600 = 0.11944$. Now calculate $0.966667 + 0.11944 = 0.978611$. Therefore, the decimal degrees equivalent is 27.978611° .

Note: Calculating degrees and parts of degrees can usually be done manually. However, if you must make multiple calculations, you may find that a calculator or computer program with degrees minutes seconds functionality allows you to quickly and accurately solve problems. CADD software programs often eliminate the need to calculate by converting angular measurements.

Angles and Intersecting Lines

Figure 7–1 shows the basic types of angles. A **full angle** is equal to 360° or 2π radians. A **straight angle** is equal to 180° or π radians. A **reflex angle** is an angle between 180° and 360° . A **right angle** is

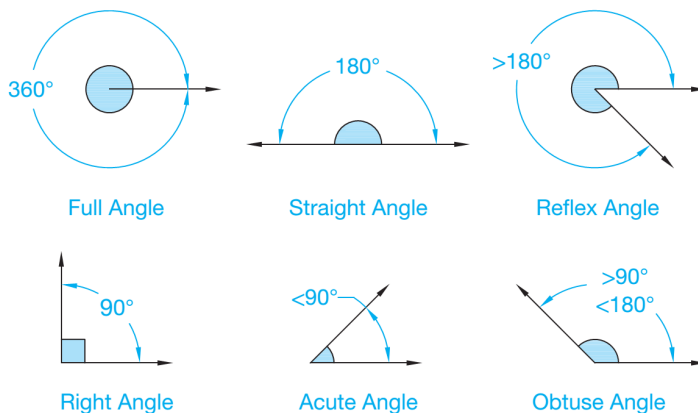


Figure 7–1. The basic types of angles.

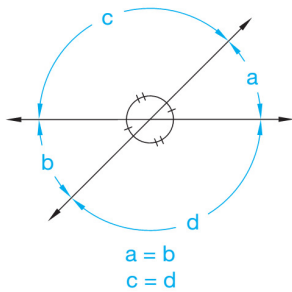
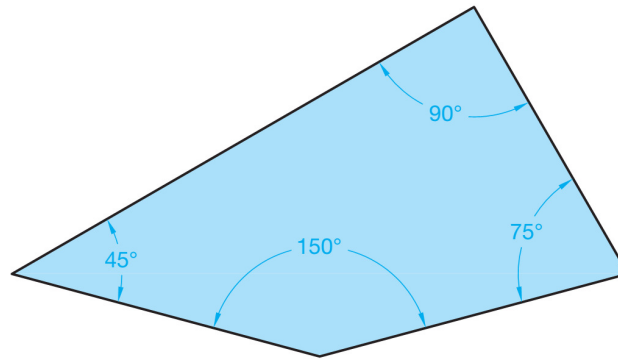


Figure 7-2. Opposite angles of intersecting lines are equal.



$$75^{\circ} + 90^{\circ} + 45^{\circ} + 150^{\circ} = 360^{\circ}$$

Figure 7-3. All angles of a four-sided polygon will equal 360° when added.

equal to 90° or $\pi/2$ radians. Two lines that form a **right angle** are **perpendicular**. An angle less than 90° is called an **acute angle**. An angle between 90° and 180° is called an **obtuse angle**. When two lines intersect, the opposite angles are equal (see Figure 7-2).

A **polygon** is a closed geometric figure with three or more sides. The sides of a polygon are straight line segments. A **regular polygon** is a closed geometric figure with three or more equal sides and equal angles. A four-sided polygon closes if all included angles equal 360° , as shown in Figure 7-3. An **included angle** is the angle formed between the vertex and the two sides. Use the following formula to calculate the total number of included angle degrees in polygons with more than four sides, where n = the number of sides:

$$(n - 2) \times 180^{\circ} = \text{Total degrees}$$

For example, make the following calculation to determine the total included angle degrees of an eight-sided polygon:

$$(8 - 2) \times 180^{\circ} = \text{Total degrees}$$

$$6 \times 180^{\circ} = 1,080^{\circ}$$

Directions

The direction of a line is expressed as a horizontal angle from a reference line known as a meridian. A **meridian** is a fixed line designated as having zero direction. In most cases, a north-south or east-west line carries the zero designation. **True north (TN)** is the location of the north pole. TN is also known as **geographic north**, **geographic meridian**, and **true meridian**. Magnetic north (MN) is where the compass north arrow points. MN is about 1,000 mi. away from TN. MN is sometimes referred to as **magnetic compass** or **magnetic meridian**. **Grid north (GN)** consists of the north-south lines of a grid mapping system such as the Universal Transverse Mercator (UTM) and the State Plane Coordinate (SPC) described in Chapter 6. When you see a note on a drawing, such as UTM grid and 2016 MN, this means



(a)



(b)

Figure 7-4. (a) An antique theodolite. (b) A modern theodolite.
(Figure (a) Gary Paul Lewis/Shutterstock, (b) Dmitry Kalinovsky/Shutterstock)

that the GN given refers to the UTM grid system and MN established in the year 2016. The angular variation between TN and GN is often given in a map legend.

Angular measurements taken by surveyors are normally taken from north or south and then measured to the east or west. A magnetic surveyor's compass was traditionally used to calculate the direction of a line. Later, surveyors used theodolites to measure direction (see Figure 7-4a). Theodolites are still in use today, but typically in the modern electronic digital theodolite transit form (see Figure 7-4b). Today, surveyors most often use electronic instruments such as the total station shown in Figure 7-5, and global navigation satellite systems (GNSS), to measure horizontal and vertical directions.

Magnetic Declination (MD)

The meridian indicated by the needle of a magnetic compass seldom coincides with the true meridian. Figure 7-6 shows a magnetic compass. The horizontal angle between the magnetic meridian and the true meridian, at any point, is called the **magnetic declination (MD)**, or **magnetic variation (MV)**. The MD is either east magnetic



Figure 7-5. A total station measures horizontal and vertical distances and angles.
(Courtesy of Topcon)



Figure 7-6. The meridian indicated by the needle of a magnetic compass seldom coincides with the true meridian.
(Hank Frentz/Shutterstock)

declination (EMD) or west magnetic declination (WMD) according to the direction the arrow of the compass points from TN given a particular location on the Earth's surface.

MD is updated periodically because of continuous changes in its value. Figure 7-7 shows an example of a compass reading displaying the angle between geographic north and MN as the MD. Magnetic declination is measured in degrees and mils. Most maps carry the MD for a specific year and the amount of annual change in degrees. The change is indicated as easterly or westerly, and records whether the compass is pointing east of TN (easterly), or west of TN (westerly). After calculating the annual change, the amount must be either added to or subtracted from the angle of declination. Figure 7-8 shows GN and MN in relationship to TN. This example was taken from the margin of a quadrangle map. Figure 7-9 shows a representation of how the MD changes in different locations in the U.S.

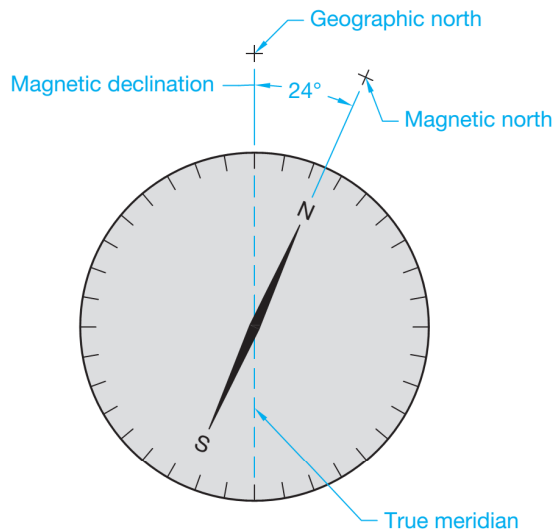
Current map reproduction technology allows most maps to be updated frequently. The frequency of map update schedules is generally determined by the specific agency, the technology, and the number of maps in the system used by the agency or organization where the maps are created. Some agencies update their maps quarterly, and some update a certain percentage of maps each year. Some maps, such as radar and satellite maps, can be updated in minutes.

Note: The National Centers for Environmental Information (NCEI) website at www.ncei.noaa.gov provides current information about magnetic declination.

Azimuth

An **azimuth** is a horizontal angle measured in a full circle from a reference line, generally north-south, in a clockwise direction. Azimuths can have a value from 0° to 360° (see Figure 7-10). A line has a

Figure 7-7. An example of magnetic declination.



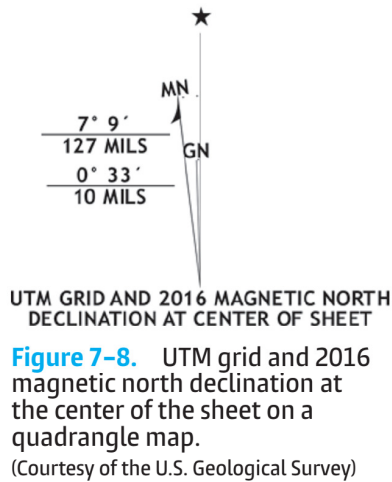


Figure 7-8. UTM grid and 2016 magnetic north declination at the center of the sheet on a quadrangle map.
(Courtesy of the U.S. Geological Survey)

forward and back azimuth. The forward azimuth is 180° less than or 180° greater than the back azimuth depending on which endpoint of the line is the vertex of the angle (see Figure 7-10).

A **true azimuth (TA)** is a horizontal angle measured using TN as the reference line. A **magnetic azimuth** is measured with MN as the zero line. The magnetic compass is used only as a check on more accurate methods and as a way to obtain approximate values for angles. Magnetic azimuths may differ from the MN, depending on local magnetic attractions. A **local attraction** is any local influence that causes the magnetic needle to deflect away from the magnetic meridian. Local attractions include steel and iron structures such as underground utilities, power lines, and buildings; and iron ore deposits. Sometimes local attractions greatly alter compass readings.

Figure 7-11 shows formulas that are used to calculate TA. The following examples show how to calculate TA, given magnetic azimuth and MD.

Example: Calculate the true azimuth given a 30° magnetic azimuth and a 20° east magnetic declination. Substituting the values into $TA = \text{magnetic azimuth} + \text{east magnetic declination}$, $TA = 30^\circ + 20^\circ = 50^\circ$ true azimuth.

Example: Calculate the true azimuth given a $70^\circ 20' 30''$ magnetic azimuth and a $20^\circ 5' 40''$ east magnetic declination. Substituting the values into $TA = \text{magnetic azimuth} + \text{east magnetic declination}$, $TA = 70^\circ 20' 30'' + 20^\circ 5' 40'' = 90^\circ 25' 70'' = 90^\circ 26' 10''$.

Example: Calculate the true azimuth, given a 217° magnetic azimuth and a $7^\circ 5'$ west magnetic declination. Substituting the values into $TA = \text{magnetic azimuth} - \text{west magnetic declination}$, $TA = 217^\circ - 7^\circ 5' = 216^\circ 60' - 7^\circ 5' = 209^\circ 55'$.

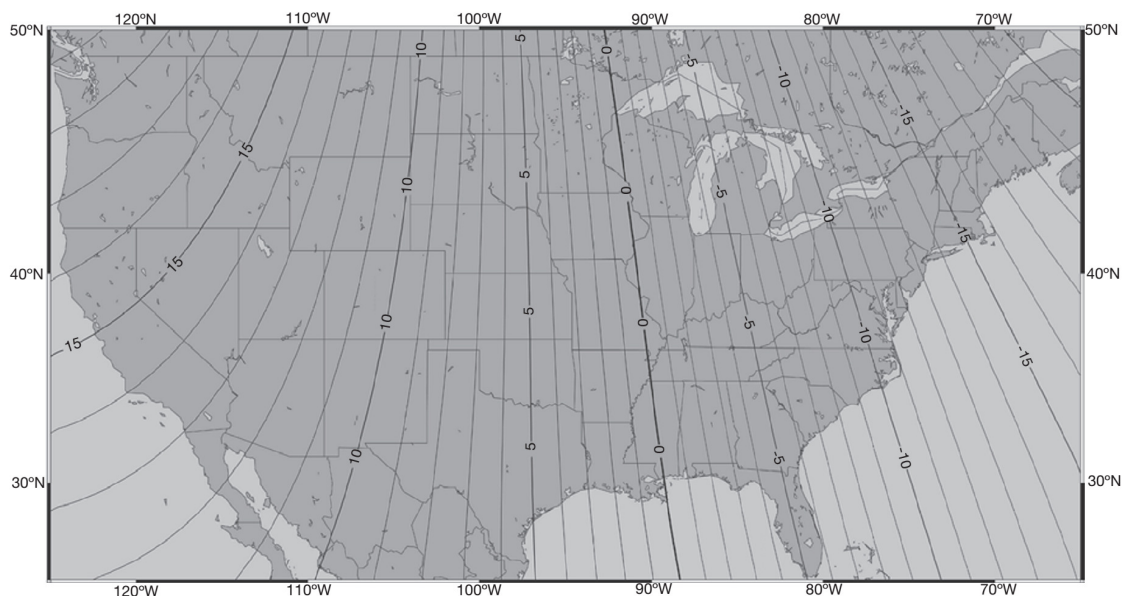


Figure 7-9. Magnetic declination changes throughout the United States.
(Courtesy of the National Centers for Environmental Information)

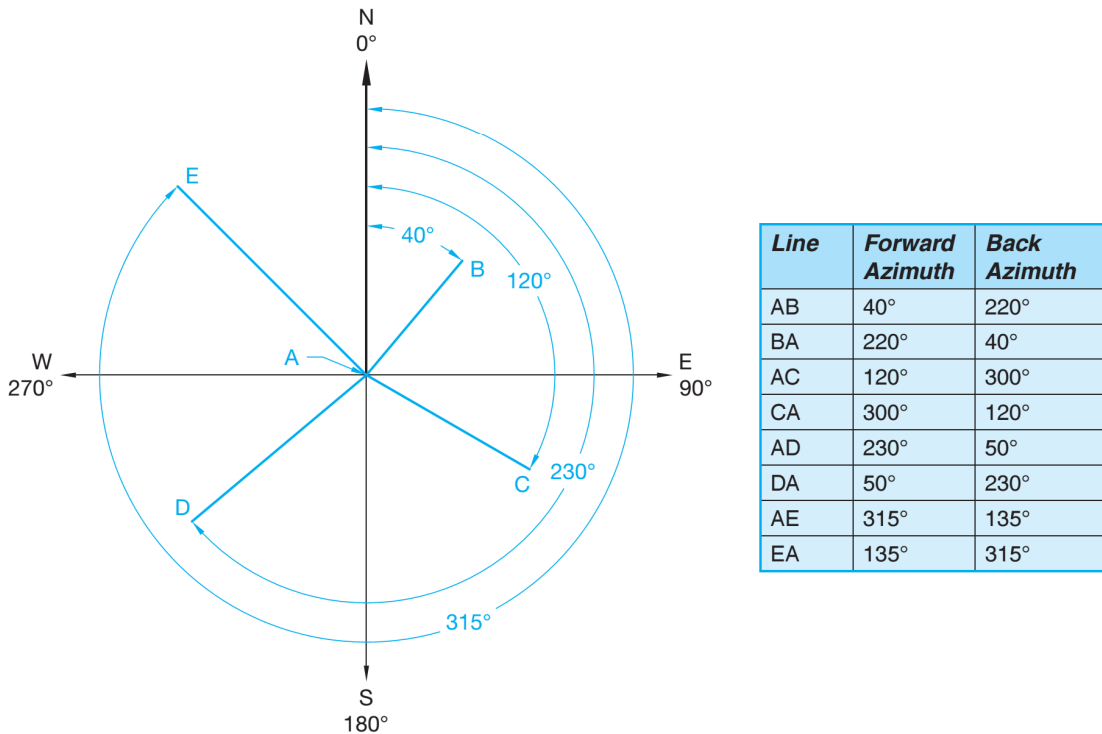


Figure 7-10. Describing the direction of lines using azimuths.

Figure 7-11. Formulas used to calculate true azimuth, given magnetic azimuth and magnetic declination.

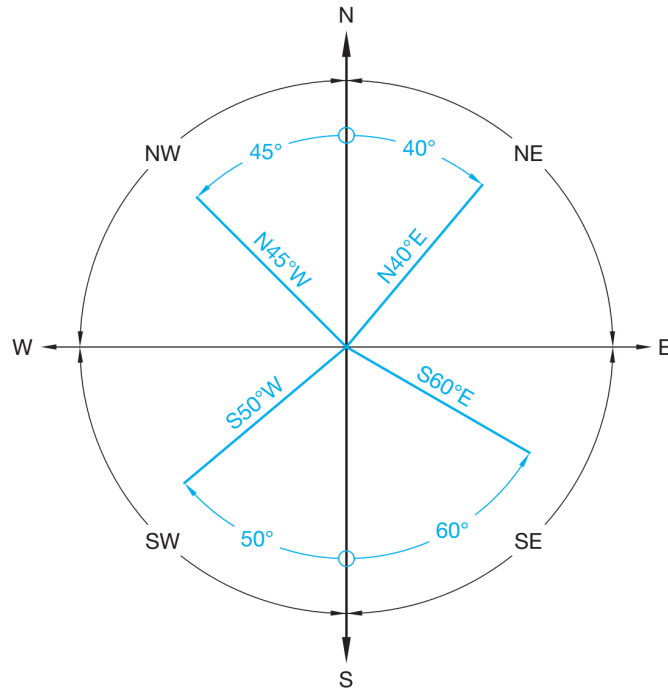
True Azimuth
TA = Magnetic azimuth + East magnetic declination
TA = Magnetic azimuth – West magnetic declination

Note: A **grid azimuth** is established for a rectangular survey system so that the north-south grids of the survey are used as the reference, or zero line. You can see grid azimuth used when you explore the Public Land Survey System (PLSS) explained in Chapter 9.

Bearing

The **bearing** of a line is its direction with respect to one of the quadrants of the compass. Bearings can have a value from 0° to 90°. Bearings are measured clockwise or counterclockwise, depending on the quadrant, and starting from north or south. A bearing is named by identifying the meridian, north or south; the angle; and the direction from the quadrant, east or west. For example, a line with a bearing written as N55°25'36"E means the 55°25'36" angle is measured from north toward east and is located in the northeast quadrant of the compass. Figure 7-12 shows examples of bearings.

Figure 7-12. Bearings are measured clockwise or counterclockwise, depending on the quadrant, and starting from north or south.



Bearings are specified as either true bearings or magnetic bearings. A surveyor identifies true bearings with a note such as: Bearings are referred to the true (north-south) meridian. The bearings are corrected by applying the MD for the correct year and day. When you draw bearing lines, plot the corrected bearings as specified by the survey. The completed map should indicate with a note that the bearings are true bearings.

Azimuths can be converted into bearings and bearings can be converted to azimuths. For example, an azimuth of $245^{\circ}14'22''$ is in the SW quadrant, or measured from south to west. A measurement from north clockwise to south is half a circle, or 180° . Therefore, subtract 180° from $245^{\circ}14'22''$ to find the bearing of $S65^{\circ}14'22''W$.

Traversing

A **traverse** is a series of continuous lines connecting points called **traverse stations**, or **station points**. The lengths of the lines connecting the points and the angles between the lines are measured during a traverse. Traverses can be open or closed depending on whether the traverse begins and ends at control points. The surveyor's compass was originally used to lay out a traverse, with bearings read directly from the compass. Today, bearings are calculated using electronic instruments such as a total station. There are several different methods of traversing. The information that you have

learned about longitude, latitude, azimuth, and bearing can be put to use with traversing to plot routes and boundaries required for civil engineering projects.

Open Traverses

An **open traverse**, shown in Figure 7–13, consists of a series of lines that do not return to a point of beginning (POB) and do not necessarily begin or end at control points. The open traverse cannot easily be checked. Open traverses are typically employed when accuracy is not critical and estimates will satisfy the project requirements, such as for exploratory surveys.

Closed Traverses

A **closed traverse** consists of a series of lines that return to a POB or close on a different known control point. A closed traverse that closes on the POB is known as a **loop traverse** (see Figure 7–14). A closed traverse that begins and ends at known points is called a **connecting traverse**. The traverse shown in Figures 7–15 appears to be an open traverse, but is a closed traverse because it connects known points such as bench marks (BMs). The angular and linear measurements of a closed traverse can be checked for accuracy.

Traversing by Interior Angles

Closed traverses are primarily measured using interior, or direct angle traversing. The traverse proceeds either clockwise or counterclockwise around the plot and measures the interior angles. The closed loop traverse shown in Figure 7–14 is plotted using the interior angle method. Bearings can later be applied to the direct angles if required. An interior angle traverse can be run clockwise or counter clockwise. Regardless of the direction of the survey, the sum of the interior angles should equal $(n - 2) \times 180^\circ = \text{Total degrees}$, where n = the number of sides in the polygon as explained earlier in this chapter.

Traversing by Deflection Angles

A **deflection angle** is an angle that veers to the right or left of a straight line (see Figure 7–16). This deflection method of angle measurement is commonly used in route surveys. An angle to the right or left of the backsight (BS) is measured and is always 180° or less. The letter R or L is given with the angle.

When the preceding line of a survey is extended beyond the current station point, it is said to be the **prolongation of the line**. The

Figure 7–13. An open traverse consists of a series of lines that do not return to a point of beginning (POB) and do not necessarily begin or end at control points.

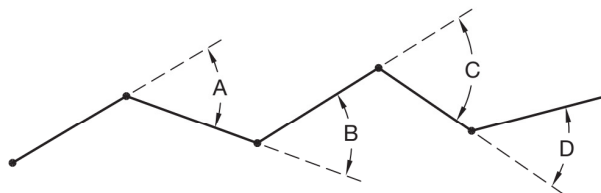
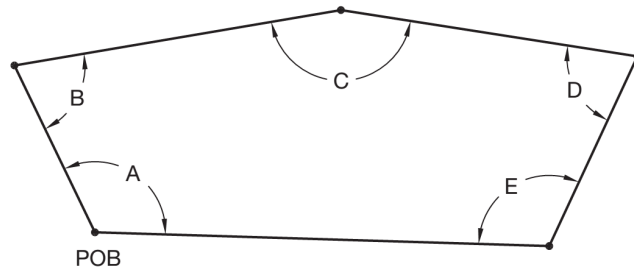


Figure 7-14. A loop traverse is a closed traverse that consists of a series of lines that return to a point of beginning (POB).



deflection angle is measured from the prolongation of the succeeding line. But the surveyor does not just measure a 180° horizontal angle from the preceding line because improper instrument adjustment may lead to error. Instead, the instrument is aimed at the BS and then flipped on its transverse, or horizontal axis, to achieve the prolongation. Then the deflection angle is measured to the next station point, or foresight (FS). When an instrument is flipped, or turned over on its transverse axis, it is said to be **plunged**. A deflection angle will close when the difference between the angles to the right and the angles to the left equals 360° .

Traversing by Angles-to-the-Right

A survey using angles-to-the-right measures the FS by turning the instrument clockwise from the BS. Closed properties are normally surveyed counterclockwise in order to create interior angles. A traverse route that is counterclockwise creates interior angles inside the polygon. The sum of the interior angles should equal $(n - 2) \times 180^\circ = \text{Total degrees}$, where n = the number of sides in the polygon as explained earlier in this chapter. Exterior angles measured clockwise are used to check the accuracy of the interior angles.

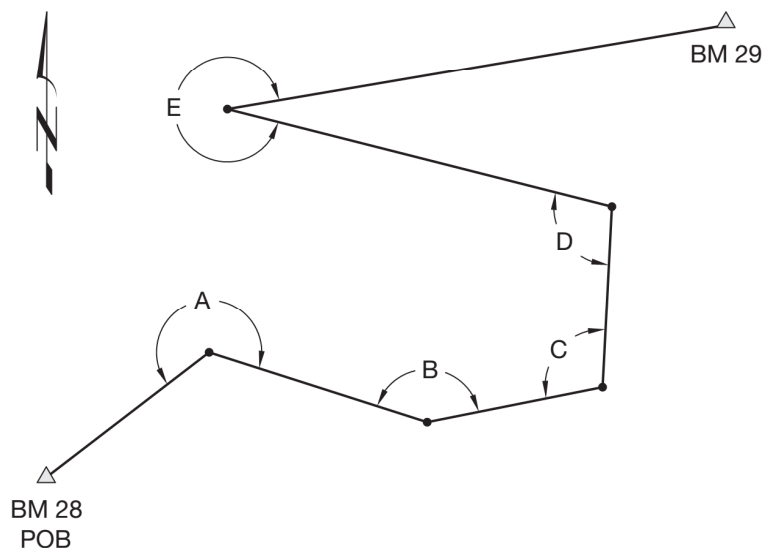


Figure 7-15. A connecting traverse is a closed traverse that begins and ends at known points, such as bench marks (BMs).

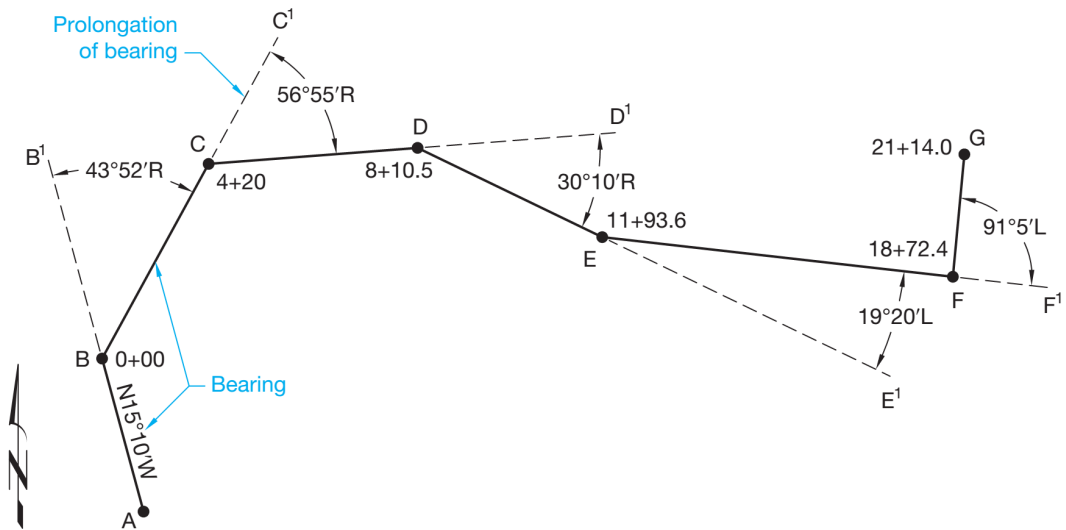


Figure 7-16. A route survey plotted using deflection angle traversing.

When the traverse route is clockwise, the angles to the right are exterior angles, or outside the polygon. The sum of the exterior angles should equal $(n + 2) \times 180^\circ = \text{Total degrees}$, where n = the number of sides in the polygon. Figure 7-17 shows the concept of interior and exterior angles-to-the-right traverses.

Traversing by Azimuths

Traversing by azimuth requires one reference line that is most often a north-south line. The reference line can be either true or magnetic. In Figure 7-18, the azimuths are measured clockwise from the north line. An angular azimuth value is given at each point in Figure 7-18 from A to E. For example, the azimuth of line AB is measured from north with the instrument located at point A. This

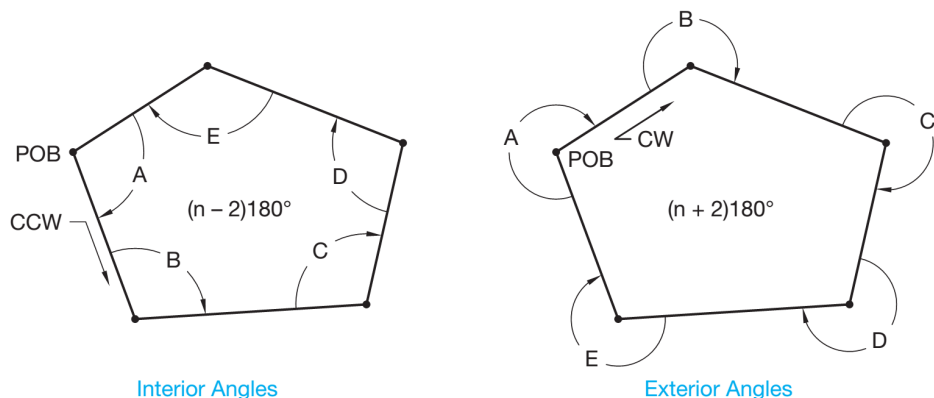


Figure 7-17. The foresight is measured by turning the instrument clockwise from the back-sight in an angles-to-the-right traverse.

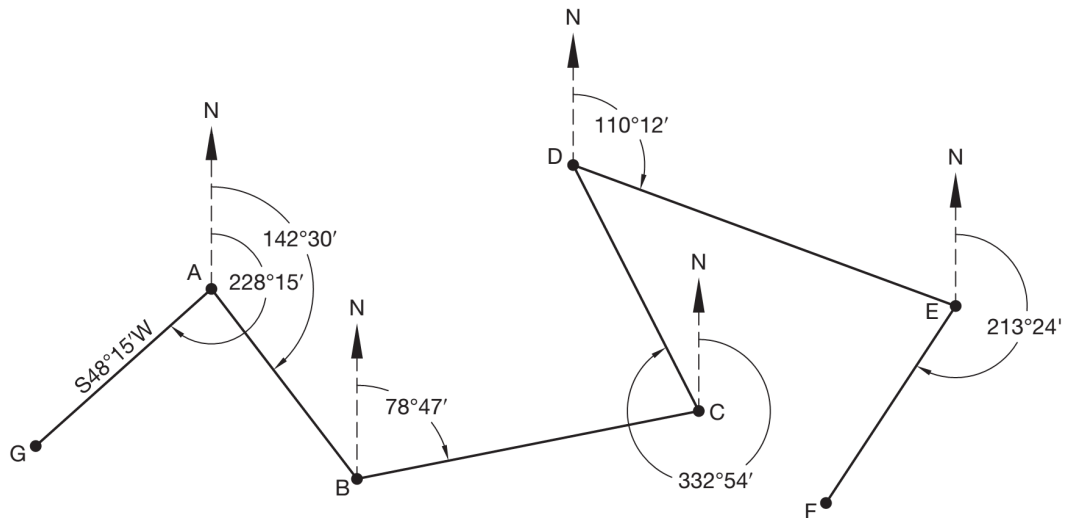


Figure 7-18. Traversing by azimuth measures each angle clockwise from north or south.

angle is $142^{\circ}30'$. Notice that line AG has also been measured, and the azimuth angle is $228^{\circ}15'$. In addition, the bearing of line AG is given as $S48^{\circ}15'W$.

Plotting Traverses

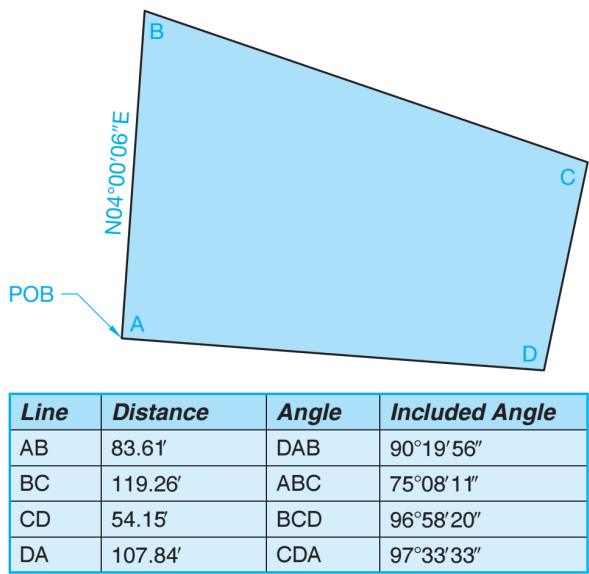
Modern survey equipment and CADD software significantly automates the process and calculations associated with plotting a traverse. However, a basic understanding of angles, directions, and traversing is a critical background for the effective civil drafter. In addition, knowing the expected outcome of a survey or a traverse allows you to better detect errors even if the computer system is able to process incorrect information. The previous concepts of angles, directions, polygon angles, and intersecting lines become important when you attempt to plot a traverse without all bearings given. The term **plot**, as used here, means to draw.

Coordinate geometry (COGO) is a means used in CADD systems for laying out survey data. The methods for laying out survey data include setting individual point coordinates and setting lines and arcs by distance and bearing. Labeling survey points, lines, and curves with lengths and bearings is often an option with COGO software. Traversing with included angles and distances can be accomplished easily with COGO. The information can be inserted into the computer system as is, from existing survey information, or it can be entered using a keyboard.

Closed Traverses

Figure 7-19 shows an example of an assignment similar to the design problems you will experience. For this example, given angles A, B, C, and D, plot the traverse and determine the bearings. Before you begin, be sure you understand the definition of bearing. Make your

Figure 7-19. An example of a typical traverse with included angles and distances given.



calculations in a clockwise direction, beginning at the POB, as shown in Figure 7-19. Use the following steps to plot the traverse:

- Step 1:** Identify the bearing of one line at a time, starting with line AB. The bearing of line AB is a known direction of N4°0'6"E, as shown in Figure 7-19.
- Step 2:** Calculate the bearing of line BC, as shown in Figure 7-20. You know that line BC is in the southeast quadrant and that angle ABC = 75°8'11". You also know that angle X = 4°0'6"; the bearing of line AB specified during step 1. Subtract angle X from angle ABC: 75°8'11" - 4°0'6" = 71°8'5". The bearing of line BC is S71°8'5"E.
- Step 3:** Calculate the bearing of line CD, as shown in Figure 7-21. You know that line CD is in the southwest quadrant and that angle BCD = 96°58'20". You also know that angle Y = 71°8'5"; the bearing of line BC calculated during step 2. Y = angle Y₁ because when two lines

Figure 7-20. Calculating the bearing of line BC.

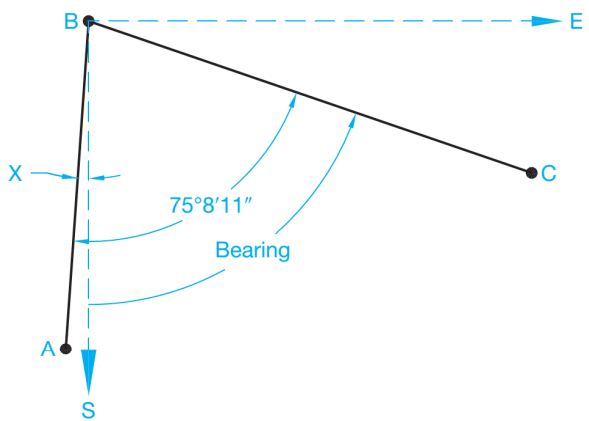
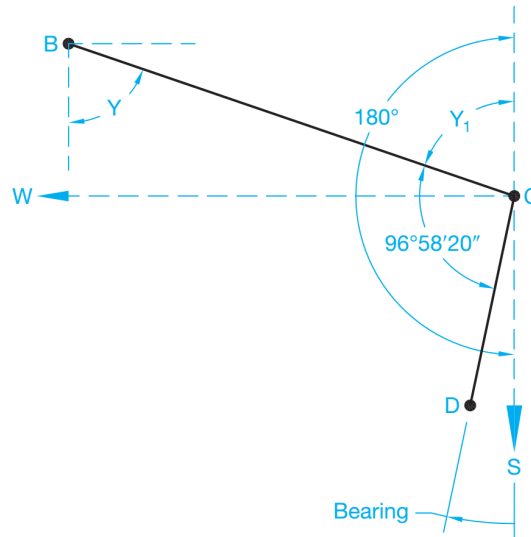


Figure 7-21. Calculating the bearing of line CD.



intersect they form two pairs of opposite angles. Add angle Y_1 to angle BCD: $96^{\circ}58'20'' + 71^{\circ}8'5'' = 168^{\circ}6'25''$. Then subtract the sum from 180° north-south: $180^{\circ} - 168^{\circ}6'25'' = 11^{\circ}53'35''$. The bearing of line CD is $S11^{\circ}53'35''W$.

Step 4: Determine the bearing of DA to return to the POB, as shown in Figure 7-22. You know that line DA is in the northwest quadrant and that angle CDA = $97^{\circ}33'33''$. You also know that angle $Z = 11^{\circ}53'35''$; the bearing of line CD calculated during step 3. Subtract Y from the angle CDA: $97^{\circ}33'33'' - 11^{\circ}53'35'' = 85^{\circ}39'58''$. The bearing of line DA is $N85^{\circ}39'58''W$. Figure 7-23a shows the complete plot layout. Figure 7-23b shows the layout data presented in a plotting table.

Latitudes and Departures

Plotting a closed traverse can also be done by calculating latitude and departure. The latitude of a line relates to the distance the line extends in a north or south direction. A **positive latitude** extends in a northerly

Figure 7-22. Calculating the bearing of line DA.

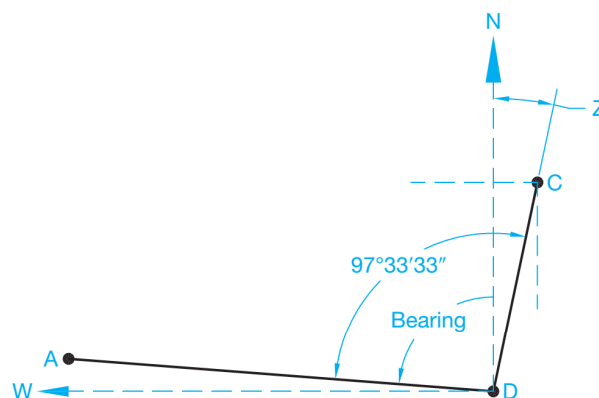
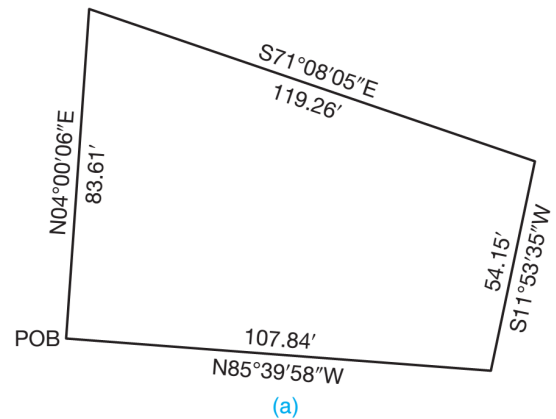


Figure 7-23. (a) Bearings and distances shown on property lines. (b) A plotting table.



Line	Bearing	Distance	Angle
AB	N04°00'06"E	83.61'	90°19'56"
BC	S71°08'05"E	119.26'	75°08'11"
CD	S11°53'35"W	54.15'	96°58'20"
DA	N85°39'58"W	107.84'	97°33'33"

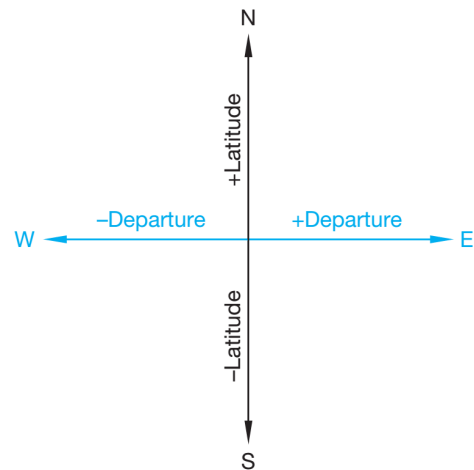
(b)

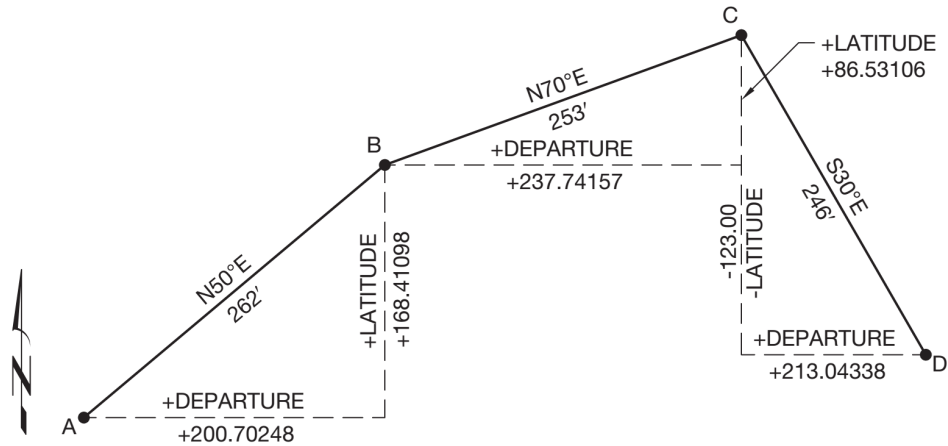
direction, while a **negative latitude** runs southerly (see Figure 7-24). The departure of a line is the distance the property line extends in an east–west direction. Lines running easterly have a **positive departure**, while **negative departures** run westerly (see Figure 7-24).

A right triangle is created by a line and its latitude and departure. The latitude of a line is the vertical side of the right triangle, and the departure is the horizontal side. Figure 7-25 shows an example of latitude and departure associated with property lines. Set up a table when working with latitude and departure calculations to help keep the information organized. Latitude and departure values are calculated as follows:

$$\begin{aligned} \text{Latitude} &= \text{Distance} \times \cos \text{Bearing} \\ \text{Departure} &= \text{Distance} \times \sin \text{Bearing} \end{aligned}$$

Figure 7-24. Positive and negative latitudes; and positive and negative departures.





(a)

Station	Bearing	Distance	Cos	Sin	Latitude	Departure
A	N50°E	262'	.64279	.76604	168.41098	200.70248
B	N70°E	253'	.34202	0.9397	86.53106	237.7416
C	S30°E	246'	.86603	0.5000	-123.0000	213.0434

(b)

Figure 7-25. (a) Latitudes and departures shown on three property lines. The property line with latitude and departure create a right triangle. (b) A table setup for latitude and departure calculations.

For example, use the following calculations to determine the latitude and departure of property line AB shown in Figure 7-25:

$$\text{Latitude} = 262' \times \cos 50^\circ = 262 \times 0.64279 = +168.41098$$

$$\text{Departure} = 262' \times \sin 50^\circ = 262 \times 0.76604 = +200.70248$$

The importance of latitudes and departures lies in the plotting of a closed traverse. When a traverse is closed, the sum of the latitudes and departures is zero. Latitudes and departures are referred to as balanced when their sums equal zero. When the sum of the latitudes and departures does not equal zero, the resulting amount is the error of closure, and the data is called unbalanced. Unbalanced latitudes and departures require that slight changes be made to the latitude and departure of each property line in order to close the traverse and balance the calculations at zero.

Computer programs are available that process the information about a plot based on the bearings and distances of each property line and automatically calculate the latitudes, departures, and azimuths. If the resulting data is unbalanced, automatic adjustments are made in property lines to balance the latitudes and departures and to close the traverse. Figure 7-26 shows a set of traverse computations.

Error of Closure

Plotting a traverse is a method of checking the accuracy of a survey. When the polygon you plot closes, you know the traverse is accurate, and you have a closed traverse. An open traverse occurs when the

Traverse Computation						
Station	Azimuth	Length	Cos(Az)	Sin(Az)		
A	21° 3'	284.80	+0.93326741	+0.35918251		
B	93° 35'	210.00	-0.06250017	+0.99804503		
C	93° 3'	240.15	-0.05320745	+0.99858356		
D	201° 3'	278.75	-0.93326730	-0.35918263		
E	272° 34'	452.00	+0.04478198	-0.99899679		
		1,465.70 = total length				
Unbalanced		Balanced			Coordinates	
Latitude	Departure	Latitude	Departure	Station	X	Y
+265.795	+102.295	+265.797	+102.290	A	0.000	0.000
-13.125	+209.589	-13.123	+209.586	B	102.290	265.797
-12.778	+239.810	-12.775	+239.806	C	311.876	252.675
-206.148	-100.122	-260.145	-100.127	D	551.682	-20.246
+20.241	-451.547	+20.246	-451.554	E	451.554	-20.246
-0.015	+0.026					
Linear error of closure = 0.029 ft.						
Precision = 1 in 49,117						
Area = 2.7677 acres						

Figure 7-26. Plot information processed by a computer automatically calculates and balances latitudes, departures, and azimuths.

ends do not close. An **error of closure** is the distance between the true and calculated position of the same point. Survey data is not expected to result in an exact closure. An example of the minimum required degree of accuracy for a survey is 1:20,000 for horizontal distance measurements, $0.05' \times \sqrt{\text{miles}}$ for vertical measurements, and 6" for angular measurements.

If an error of closure is acceptably small, calculations can be used to improve the survey data. However, if an error of closure exceeds tolerable limits, the survey must be repeated to correct errors in distance and/or angle measurements. As a drafter, you should never manipulate survey data unless directed to do so by the surveyor. Figure 7-27 shows an exaggeration of the general concept of closing a traverse when the error of closure is within acceptable limits. The following basic steps outline the process.

- Step 1:** Lay out the perimeter of the plot along a straight line and label the corners, as shown in Figure 7-27b.
- Step 2:** Extend the error of closure below point A'.
- Step 3:** Connect a line from A'' to A'.
- Step 4:** Connect perpendicular lines from points B, C, and D to line AA''.
- Step 5:** Use the distance from line AA' to line AA'' at each point to compensate for the problem. The proportioned distance corrections as determined by Figure 7-27b are applied to each point in Figure 7-27c at the same angle as A is from A'.

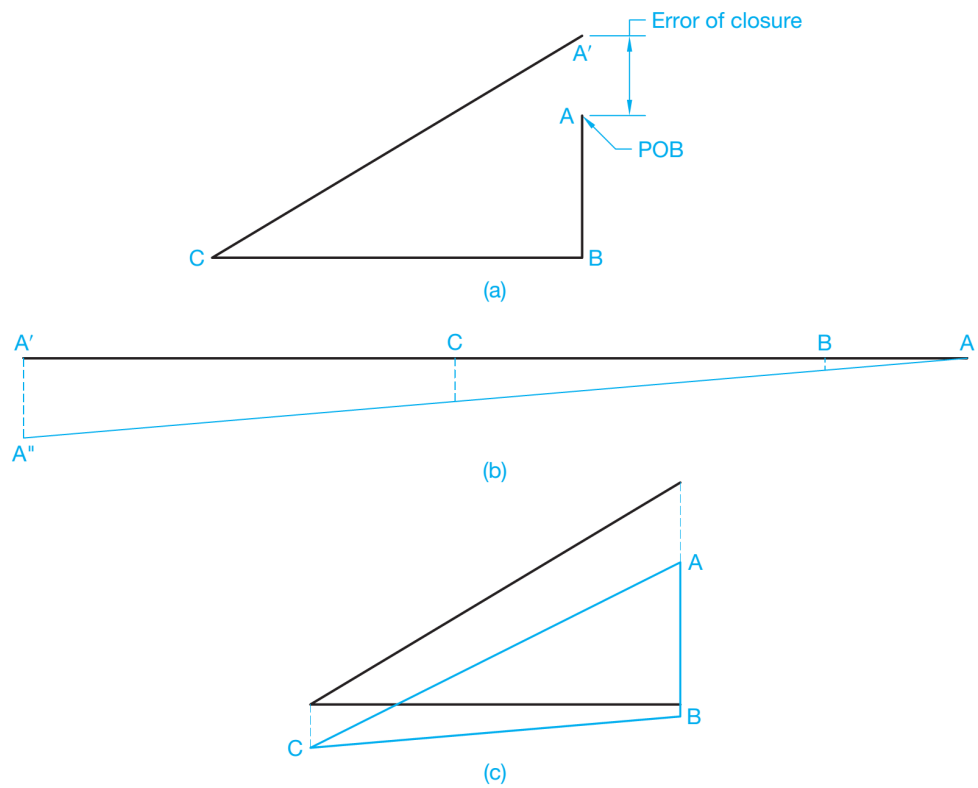


Figure 7-27. (a) Error of closure. (b) Correcting the error of closure. (c) Closed traverse.

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Choose the response that best describes each statement.

- 7-1** The amount of space, or turn between two lines, known as arms or sides, that intersect at a point known as the vertex is called a(an):
- a. Radian
 - b. Degree
 - c. Angle
 - d. Reflex
- 7-2** A mil is approximately equal to:
- a. 2π radians
 - b. π radians
 - c. $1/360$ of the circumference of a circle
 - d. $60'$
 - e. $1/6,400$ of the circumference of a circle
- 7-3** The symbol that identifies degrees is:
- a. "
 - b. '
 - c. °
 - d. ∞
- 7-4** An example of the sexagesimal numerical system is:
- a. $30^{\circ}20'45''$
 - b. 30 mi.25'
 - c. 4:30
 - d. 1.2 rad
- 7-5** To convert a degrees minutes seconds value to decimal degrees:
- a. Subtract the specified number of seconds from the number of seconds in a minute
 - b. Divide the specified number of seconds by the number of seconds in a minute
 - c. Add the specified number of seconds to the number of seconds in a minute
 - d. Multiply the specified number of seconds by the number of seconds in a minute

- 7-6** A full angle is an angle:
- Between 90° and 180°
 - Between 180° and 360°
 - Equal to 180° or π radians
 - Equal to 360° or 2π radians
 - $1/360$ of the circumference of a circle
- 7-7** A closed geometric figure with three or more sides is called a(an):
- Polygon
 - Meridian
 - Acute symbol
 - Obtuse symbol
- 7-8** The calculation to determine the total included angle degrees of a six-sided polygon is:
- $(2 + 6) \times 90^\circ = \text{Total degrees}$
 - $(6 - 2) \times 180^\circ = \text{Total degrees}$
 - $(8 - 2) \times 180^\circ = \text{Total degrees}$
 - $(8 - 2) \times 360^\circ = \text{Total degrees}$
- 7-9** The compass north arrow points to:
- Geographic north
 - Magnetic meridian
 - Geographic meridian
 - True north
- 7-10** The horizontal angle between the magnetic meridian and the true meridian, at any point, is called:
- True north
 - Magnetic north
 - Magnetic declination
 - A local attraction

Part 2

Identify whether the statement is true or false. Reword all false statements so that the meaning is true.

- 7-11** Magnetic azimuths may differ from true azimuth by several degrees.
- 7-12** Local attraction is any local influence that causes the magnetic needle to deflect away from the magnetic meridian.

- 7-13** Grid azimuth is established for a rectangular survey system so that the north-south grids of the survey are used as the reference line.
- 7-14** True azimuth given a 20° magnetic azimuth and 5° east magnetic declination is 15° .
- 7-15** Magnetic azimuth + Magnetic declination = True azimuth.
- 7-16** Bearings are always measured counterclockwise.
- 7-17** Bearings are specified as either true bearings or magnetic bearings.
- 7-18** A $N40^\circ E$ bearing equals a 40° azimuth.
- 7-19** A $N45^\circ W$ bearing equals a 45° azimuth.
- 7-20** The sum of the interior angles of a closed polygon should equal $(n - 2) \times 180^\circ$, where n = the number of sides in the polygon.

Part 3

Calculate the true azimuth given the following information.

- 7-21** Magnetic azimuth = 32° , magnetic declination = $15^\circ E$
- 7-22** Magnetic azimuth = 46° , magnetic declination = $5^\circ W$
- 7-23** Magnetic azimuth = 18° , magnetic declination = $7^\circ E$
- 7-24** Magnetic azimuth = 27° , magnetic declination = $12^\circ E$
- 7-25** Magnetic azimuth = $19^\circ 45' 12''$, magnetic declination = $4^\circ 50' 39'' E$

Part 4

Identify the type of traverse shown in the specified figure.

7-26 See Figure R7-1.

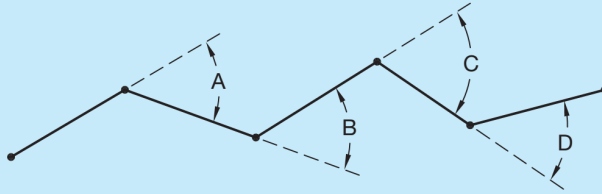


Figure R7-1.

7-27 See Figure R7-2.

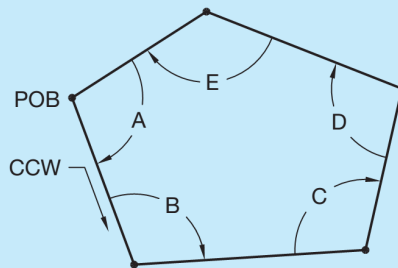


Figure R7-2.

7-28 See Figure R7-3.

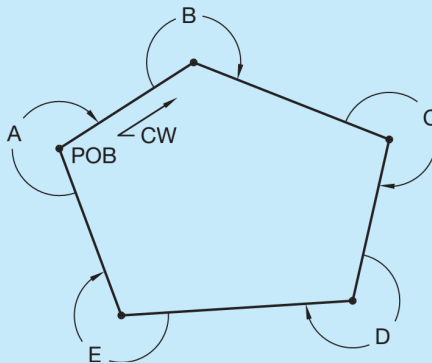


Figure R7-3.

7-29 See Figure R7-4.

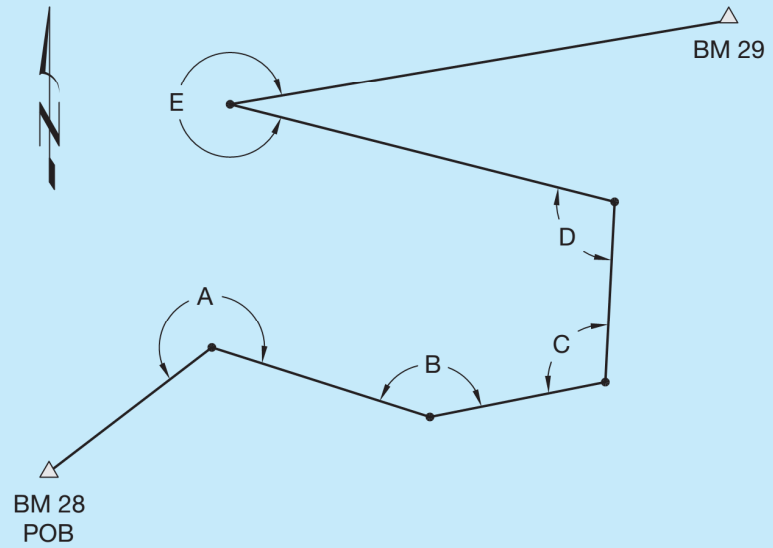


Figure R7-4.

7-30 See Figure R7-5.

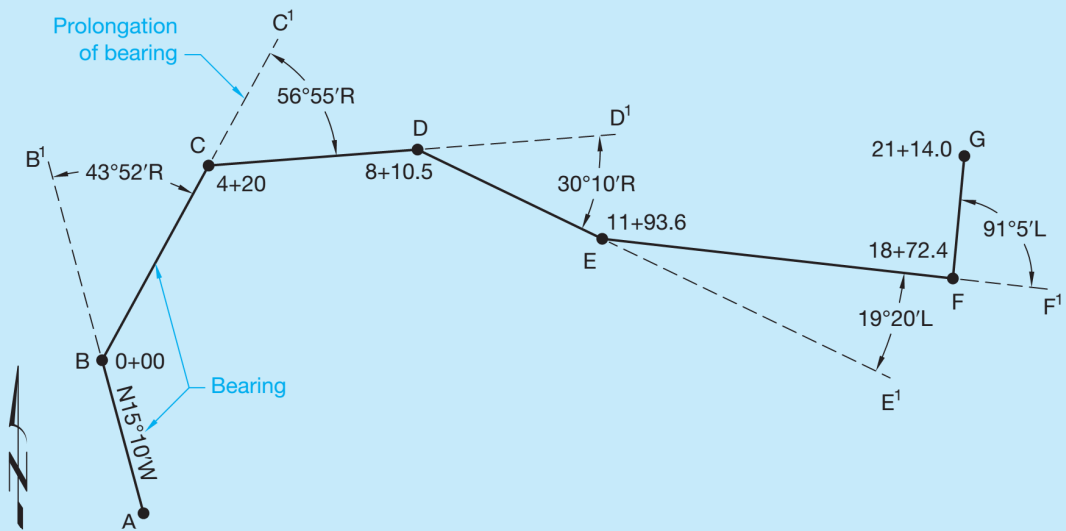


Figure R7-5.

PROBLEMS

Follow the specific instructions to complete each problem.

- P7-1** Give the azimuths of the lines AB, BC, CD, and DA shown in Figure P7-1. North is zero.

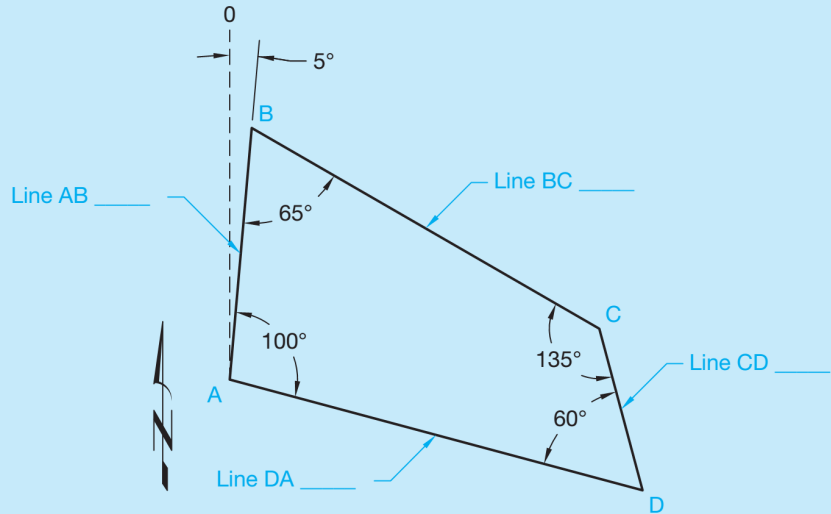
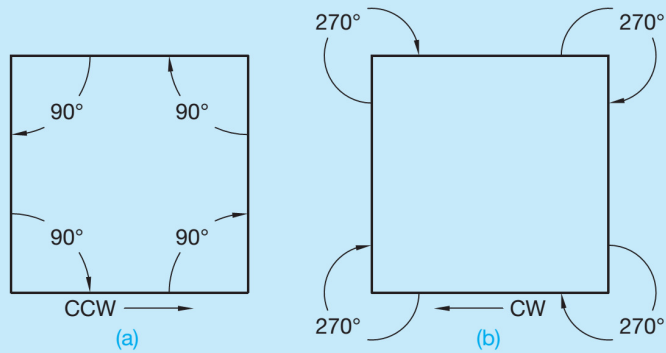


Figure P7-1.

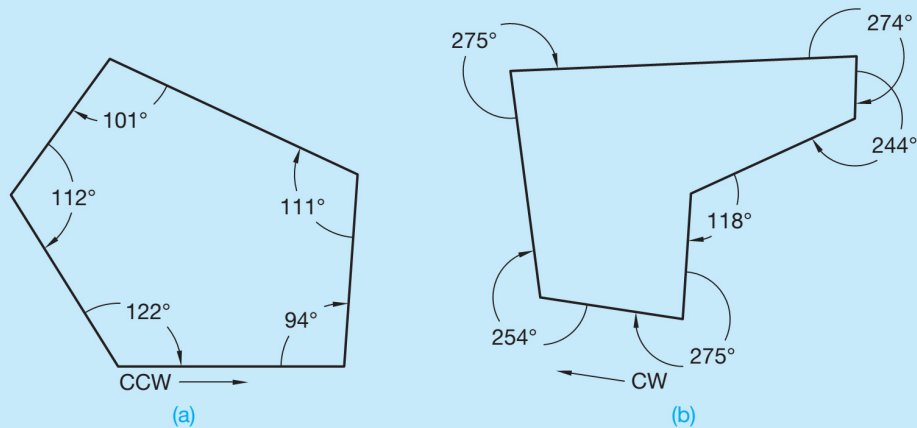
- P7-2** Give the bearings of the lines listed in Problem P7-1.
- P7-3** Convert the deflection angles for lines AB, BC, CD, DE, EF, and FG given in Figure 7-16 to azimuths and bearings.
- P7-4** Convert the azimuths for lines AB, BC, CD, DE, and EF given in Figure 7-18 to bearings.
- P7-5** The surveys of the property lines shown in Figure P7-5 were plotted using traversing by angles-to-the-right. Use the appropriate formula to verify that your calculations equal 360° for each survey.

Figure P7-5.



P7-6 The surveys of the property lines shown in Figure P7-6 were plotted using traversing by angles-to-the-right. Use the appropriate formula to verify that your calculations equal 360° for each survey.

Figure P7-6.



P7-7 Complete the table shown in Figure P7-7.

Figure P7-7.

Point	Azimuth	Bearing
A		N15°45'30"E
B		S20°W
C	270°	
D	135°30'	
E		N35°14'45"W

P7-8 Complete the table shown in Figure P7-8.

Figure P7-8.

Magnetic Azimuth	Magnetic Declination	True Azimuth
20°30'	2°15'E	
170°	10°20'W	
	15°20'W	11°15'
	20°20'15"E	149°30'
10°	15°W	

P7-9 Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download and open the Problem P7-9.dwg file with the content shown in Figure P7-9. Determine the azimuth and bearing of each line. Type your answers in the table provided.

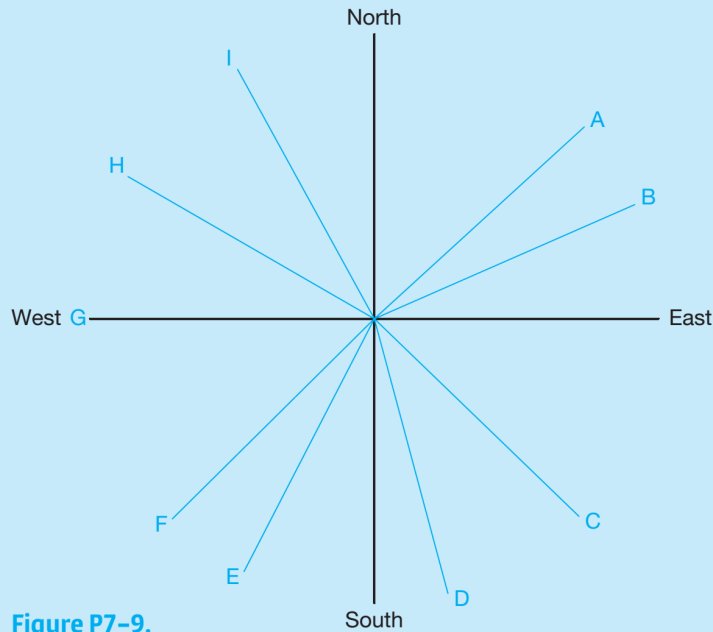


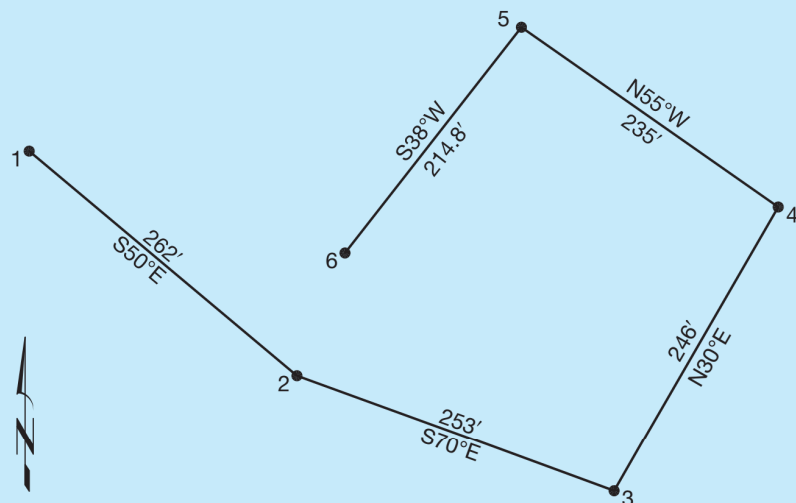
Figure P7-9.

Line	Azimuth	Bearing
A		
B		
C		
D		
E		
F		
G		
H		
I		

P7-10 Given the partial traverse shown in Figure P7-10 place the following items in the table:

- Bearing of each property line (course)
- Distance of each course
- Cosine of each bearing angle
- Sine of each bearing angle
- Latitude of each course
- Departure of each course

Figure P7-10.

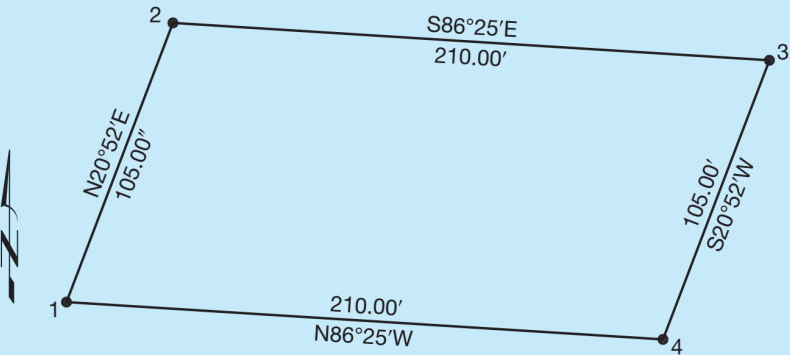


Course	Bearing	Distance	Cos	Sin	Latitude	Departure
1-2						
2-3						
3-4						
4-5						
5-6						

P7-11 Given the traverse shown in Figure P7-11 place the following items in the table:

- Bearing of each property line (course)
- Distance of each course
- Cosine of each bearing angle
- Sine of each bearing angle
- Latitude of each course
- Departure of each course

Figure P7-11.



Course	Bearing	Distance	Cos	Sin	Latitude	Departure
1-2						
2-3						
3-4						
4-1						

P7-12 Draw a traverse from the calculations and information shown in Figure 7-26.

P7-13 Plot the subdivision boundary given the northing and easting information shown in Figure P7-13. Identify the length to one-hundredth of a foot and bearing of each property line and place the information in the table. Plot the traverse at a scale of 1" = 50' on a B-size sheet and place the following items on your drawing:

- Bearing of each line (course)
- Distance of each course
- Small circles at intersections of courses
- A point number at the end of each course

- POB
- Scale
- North arrow
- Title block: Erika Subdivision, Quincey Lane at Christopher Blvd., Jean, Wisconsin

<i>Point No.</i>	<i>Northing</i>	<i>Easting</i>	<i>Length</i>	<i>Bearing</i>
1 (POB)	71394.4238	176534.3439		
2	71368.0963	176968.3491		
3	71127.4345	176950.6149		
4	71028.9085	176905.4732		
5	70969.1469	176571.7470		
6	71143.5863	176510.4833		

Figure P7-13.

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CHAPTER

8

Contour Lines

Learning Objectives

After completing this chapter, you will be able to:

- Explain the purpose of contour lines.
- Describe topographical features using contour line characteristics.
- Identify types of contour lines.
- Use interpolation to identify the location of unknown points.
- Draw contour maps.
- Describe examples of automated contour line CADD tools.

Key Terms

Elevation
Contour line
Contour interval
Topographic map
Quadrangle map
Ridge
Saddle
Index contour
Major contour
Intermediate contours
Minor contours
Supplementary contour
Vertical datum
Control point survey
Interpolation
Uniform slope theory
Radiation
Transit station
Triangulated irregular network (TIN)
Quantities

The word *topography* originates from the Greek words *topos*, place, and *-graphia*, writing. A common method of writing, or drawing, a place is to represent differences in elevation with contour lines. **Elevation** is the height of a geographic location above or below a theoretically exact reference point, axis, or plane. A **contour line** is a line that connects points of equal elevation. This chapter introduces the theory, concepts, and creation of contour lines. In order to interpret and edit topographic maps, it is important that you understand what topographical characteristics contour lines represent and how contour lines are created.

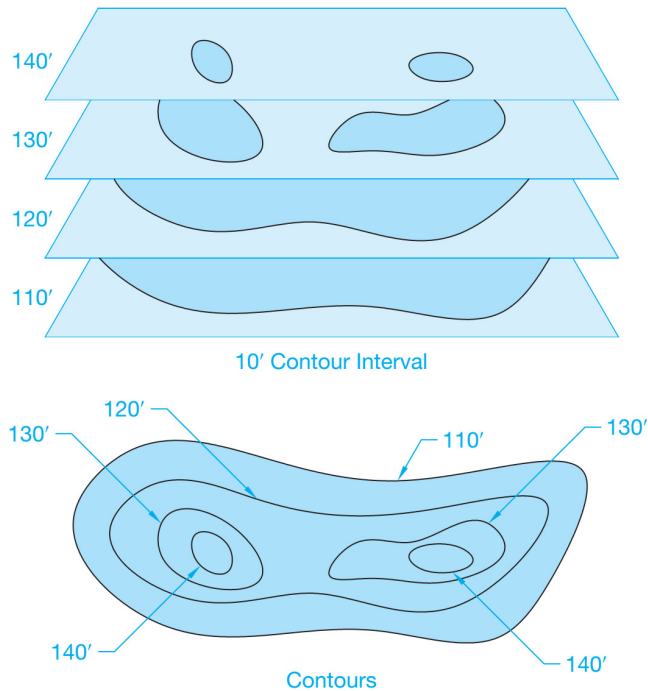
Contour Lines

Contour lines describe geographical features. A good way to visualize the concept of contour lines is to observe the effects of water lap marks around the shore of a lake or reservoir (see Figure 8–1). The water level represents one contour line because the level of the reservoir is the same in all places. By late summer, many reservoirs are lowered considerably, and previous water levels are seen as contour lines. As you can see in Figure 8–1, contour lines do not touch, and are generally parallel to each other. One line can be followed around the reservoir until it closes on itself. The **contour interval** is the vertical



Figure 8–1. Contour lines formed by lapping water at different levels in a reservoir.
(Jill Lang/Fotolia)

Figure 8-2. Contours and the concept of contour interval.



elevation difference between contour lines. Figure 8-2 shows the relationship between actual elevations and how the contour lines appear on the map. Each horizontal plane represents an additional 10' in elevation from the horizontal plane below. The contour interval in the Figure 8-2 example is 10'.

A **topographic map** accurately shows the shape of the Earth using contour lines. A common example of a topographic map is a **US Topo** quadrangle map published by the U.S. Geological Survey (USGS) (see Figure 8-3). A **quadrangle map** is a map of an area of the Earth's surface with a grid showing geographic location. Contour lines are also seen on many different types of civil engineering drawings, such as the portion of a site plan for a concrete irrigation structure removal project shown in Figure 8-4. Chapter 9 explains more about site plans.

Slopes

The spacing of contour lines is determined by the grade, or slope, of the land. Contour lines are drawn at equal changes in elevation, such as every 2, 5, or 10'. On steep terrain, contour lines are close together because changes in elevation occur quickly (see Figure 8-5). On terrain that slopes gradually, contour lines are farther apart because it takes longer to reach a change in elevation (see Figure 8-6).

Contour lines that are approximately equally spaced depict a uniform slope. Close contour lines at the upper or lower portion of a slope represent steeper topography at the top or bottom of a hill.



Figure 8-3. A portion of the Mauna Kea, Hawaii quadrangle map.
(Courtesy of the U.S. Geological Survey)

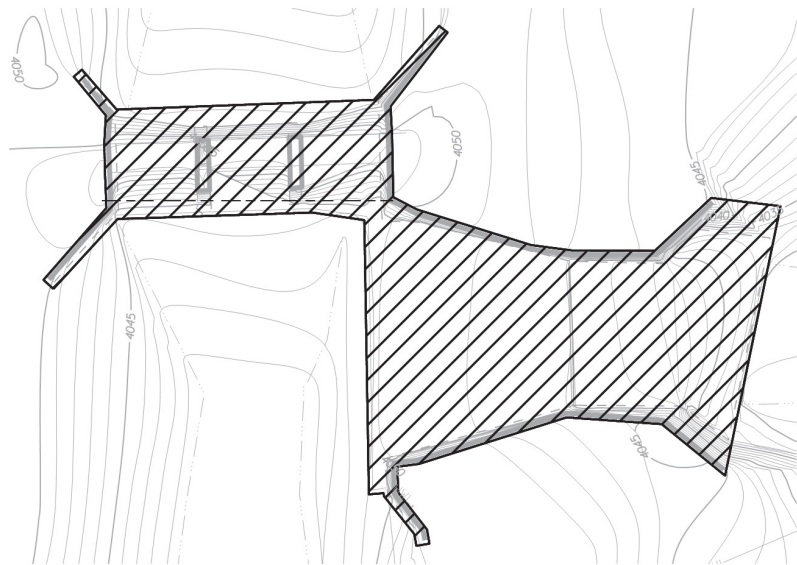


Figure 8-4. A portion of a site plan for a concrete irrigation structure removal project.
(Courtesy of Sage Civil Engineering)

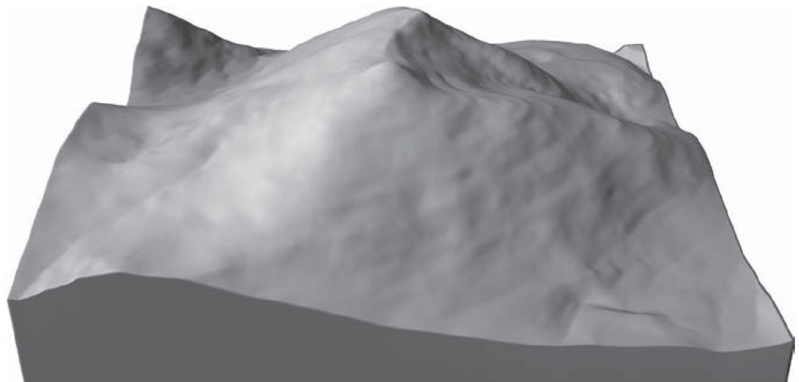
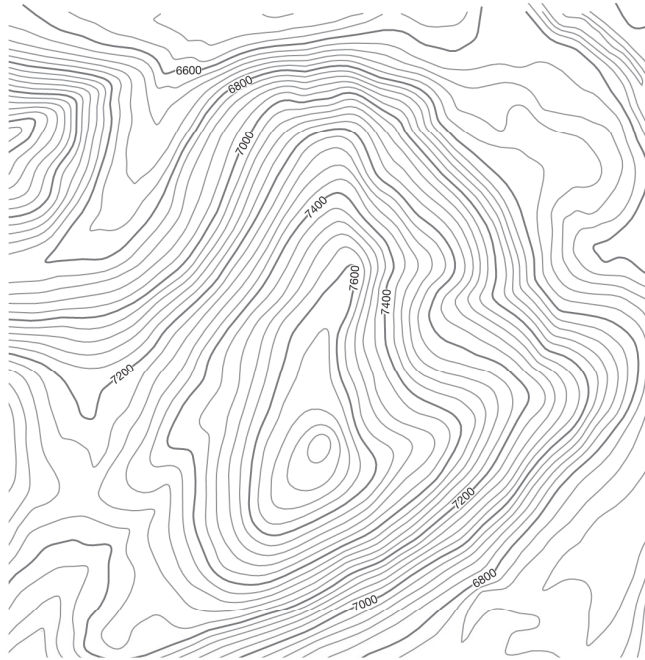


Figure 8-5. Contour lines representing steep slopes.
(Map courtesy of the U.S. Geological Survey)

A concave slope is steeper toward the top (see Figure 8-7a). A convex slope is steeper toward the bottom (see Figure 8-7b).

Ridges and Valleys

Contour lines form a “U” shape around hills and ridges. A **ridge** is a long narrow area of ground at higher elevation. The bottom of the U points downhill (see Figure 8-8a). Contour lines form a “V” at a valley between two hills. The bottom of the V points up the valley, or upstream, if there is water draining through the valley (see Figure 8-8b). Contour lines form an “M” near the intersection of valleys. The peaks of the M point up the valley (see Figure 8-8c).

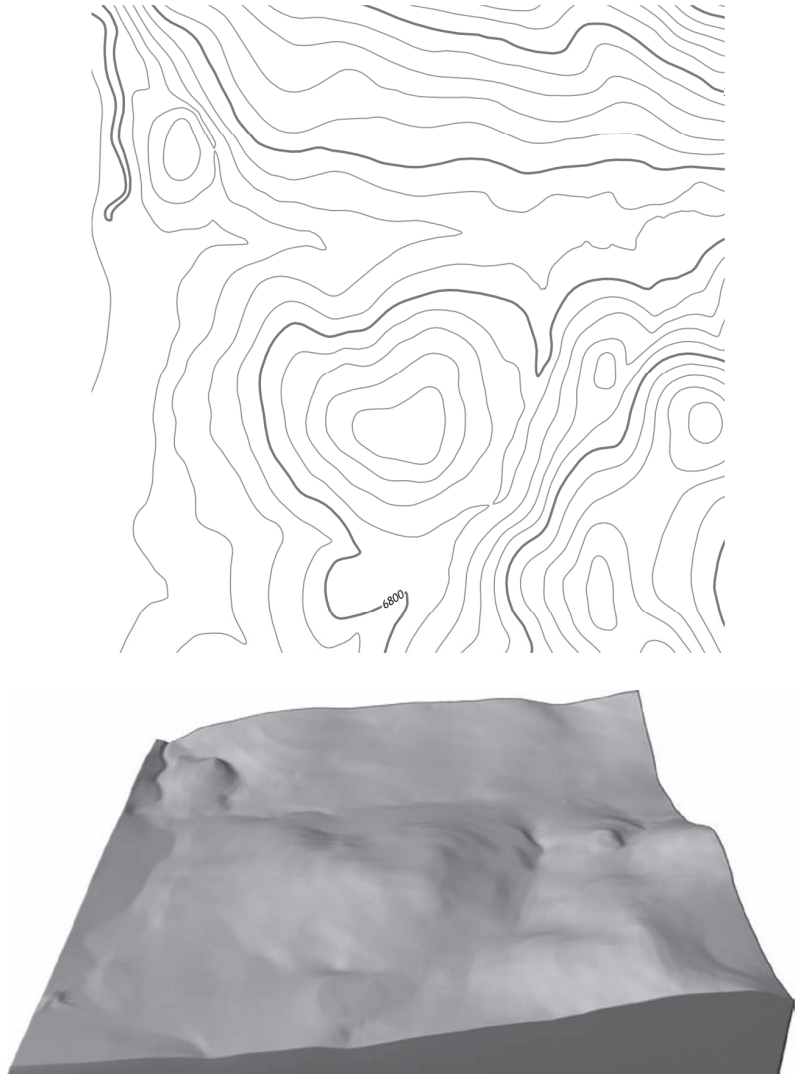


Figure 8-6. Contour lines showing gentle slopes.
(Map courtesy of the U.S. Geological Survey)

Valleys that include streams are typically easy to identify on topographic maps, as streams are usually shown. However, if you do not see stream symbols you can still identify valleys by “V” and “M” shape contour lines.

Relief Features

The features shown in Figure 8-9 are easy to recognize on contour maps. The peak of a hill or mountain shown in Figure 8-9a is a common feature and may be accompanied by an elevation. The contour lines depicting a hill form circles of ever-decreasing diameter. Two high points or peaks side by side form a saddle (see Figure 8-9b). A **saddle** is a low spot between two peaks.

Figure 8-7.
 (a) Concave slope.
 (b) Convex slope.
 (Maps courtesy of the U.S.
 Geological Survey)

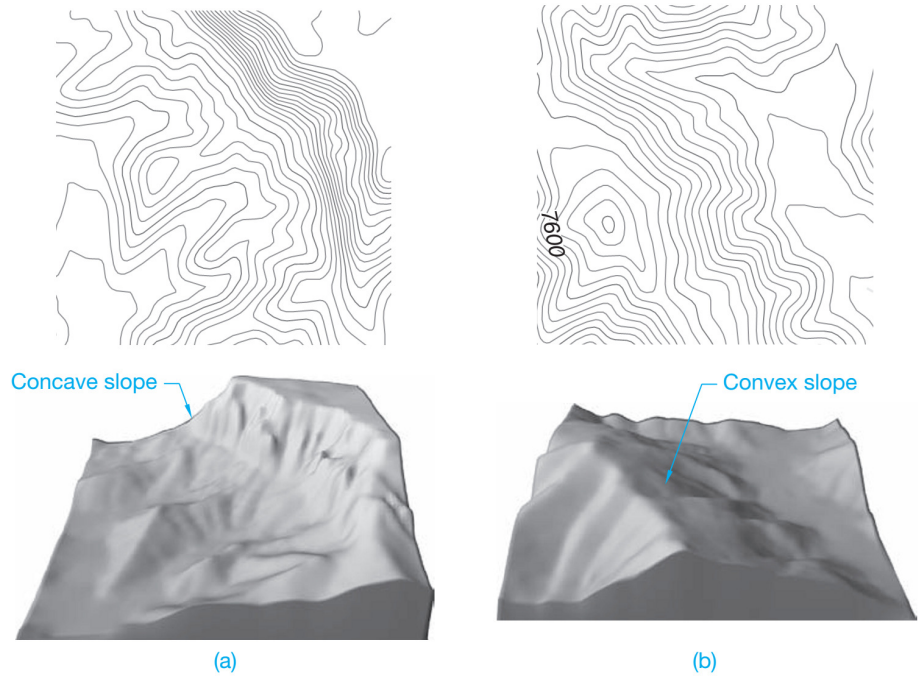
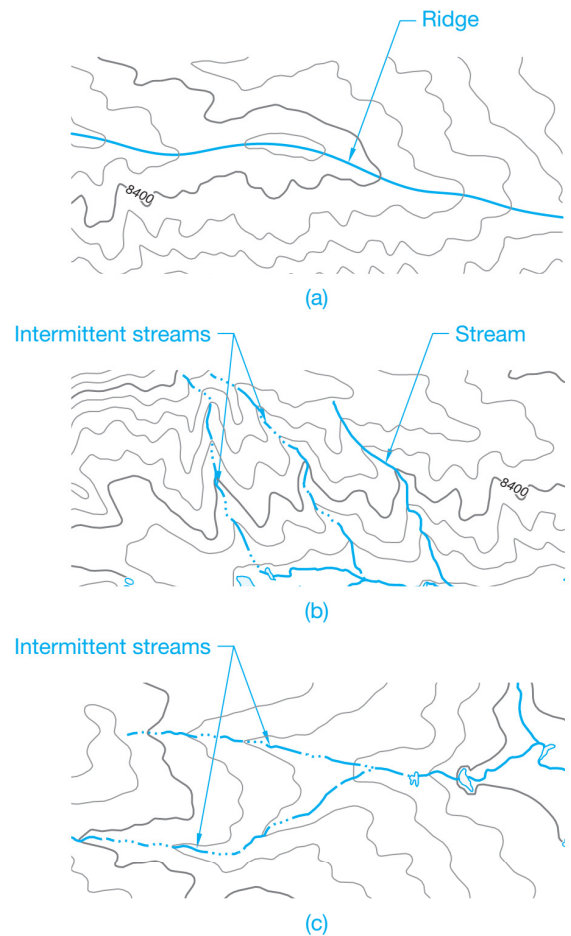


Figure 8-8. (a) Contour lines form a “U” around ridges. The bottom of the U points downhill. The colored line identifies the top of the largest ridge and is for reference only. (b) Contour lines form a “V” at a valley. The bottom of the V points up the valley, or upstream. (c) Contour lines form an “M” above intersecting valleys, or stream junctions. The peaks of the M point up the valleys, or upstream.
 (Maps courtesy of the U.S. Geological Survey)



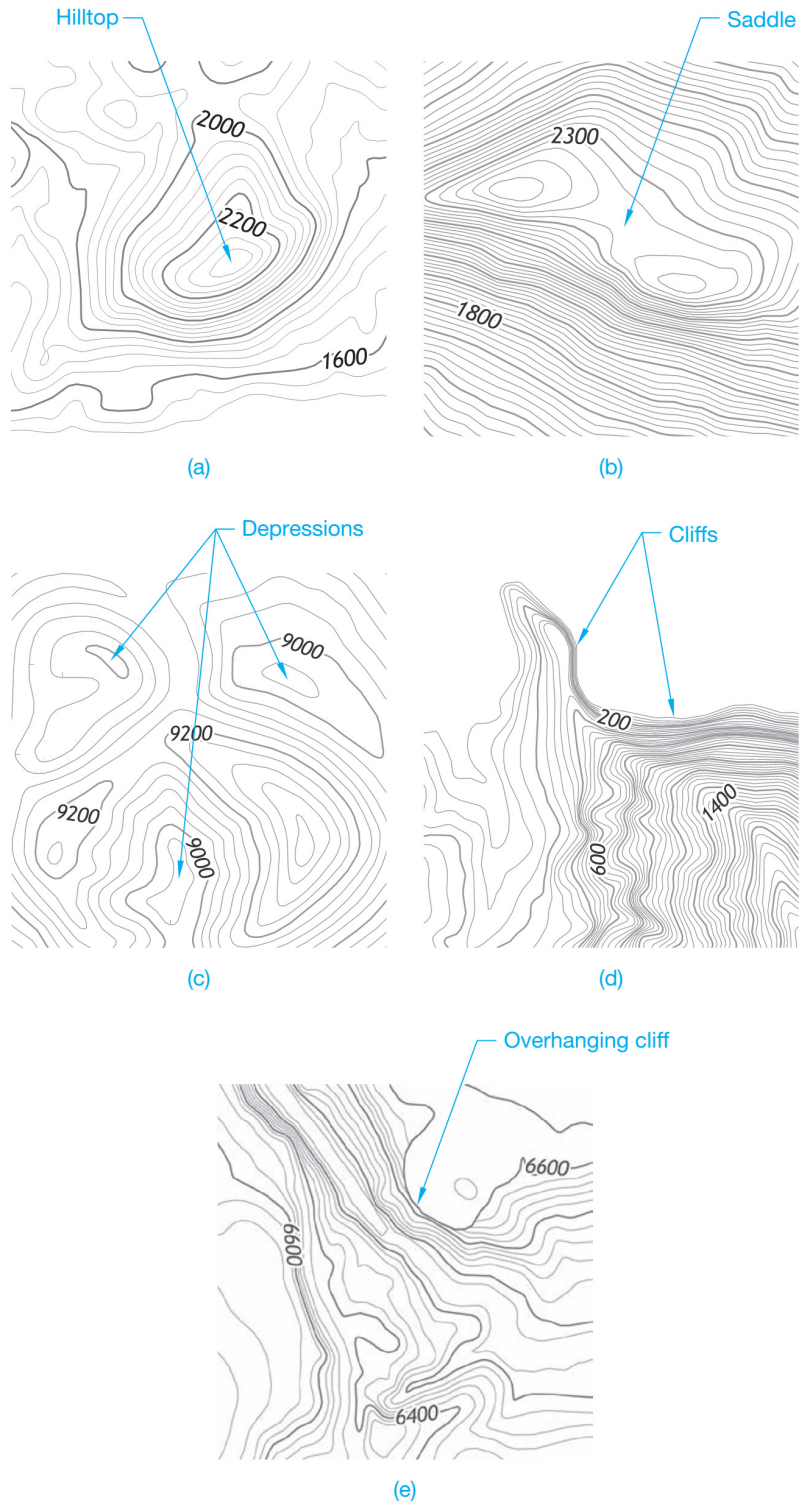


Figure 8-9. (a) Dome-shaped hill. (b) Saddle. (c) Depressions. (d) Cliffs. (e) Overhanging cliff.
(Maps courtesy of the U.S. Geological Survey)

The special contour line shown in Figure 8–9c is used to represent a depression. The contour line has short lines pointing into the depression. Depressions include human-made features such as quarries and pits, and natural features such as sinkholes and volcanic craters.

Contour lines that touch or nearly touch portray sheer cliffs and vertical rock walls of canyons (see Figure 8–9d). The overhang cliff shown in Figure 8–9e is the exception on a contour map when contour lines cross. The lower contour lines go under the higher contour lines. Overhanging cliffs are typically found in rocky, highly sculpted, and/or mountainous terrain.

Note: Contour lines may or may not accurately represent an overhanging cliff depending on the map scale and drawing requirements. Overhangs on quadrangle maps, for example, often appear as cliffs with a note specifying an overhanging cliff or the geographic name of the feature.

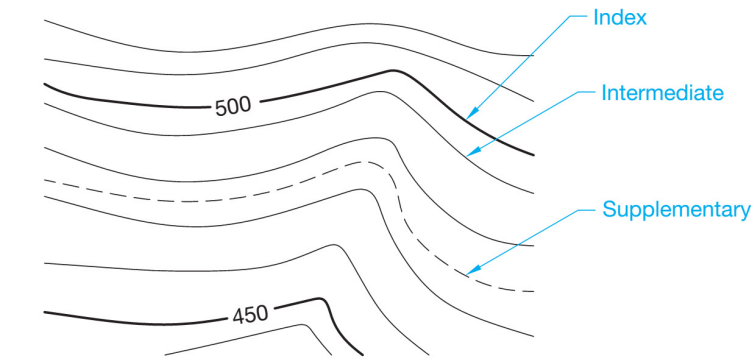
Types of Contour Lines

Each contour line represents a specific elevation. Different types of contour lines are used to identify elevation and improve the readability of a map. Figure 8–10 displays the three different types of contour lines you may typically see on a map. The appearance of contour lines can vary, especially on civil engineering drawings, based on selected drawing standards. Figure 8–10 includes some basic contour line conventions to consider when drawing contours.

Index Contours

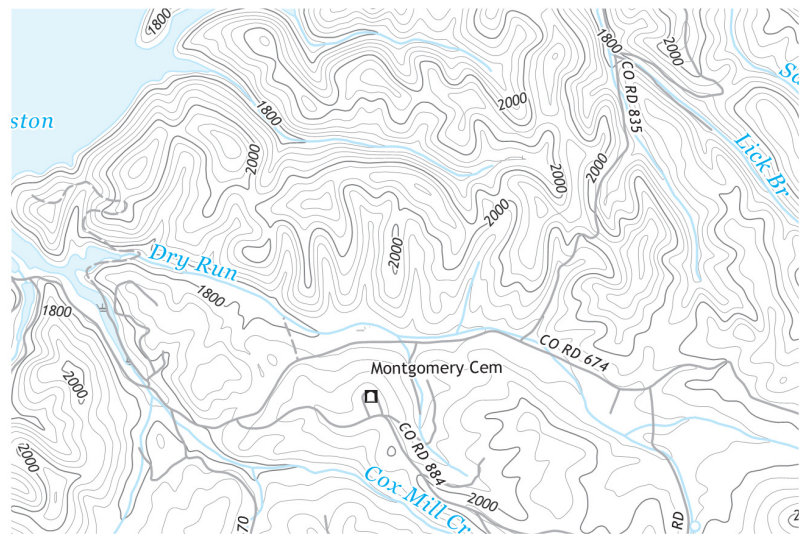
An **index contour**, also known as a **major contour**, is every fifth contour line on a topographic map. Index contours aid the map reader in finding references and even-numbered elevations. Index contours are often thick, solid or dashed lines broken at intervals with a note that specifies the elevation of the line. Figure 8–10a shows two index contours identifying 450 and 500' elevations.

Most topographic maps show written elevations only on index contour lines. Index contour labels are normally enough to give the map reader sufficient reference values from which to work. Some civil engineering drawings, such as certain property plats, highway maps, and special maps of many other kinds require every contour to be labeled. In this case, you must use good layout and spacing techniques to achieve a balanced and uncluttered appearance. Elevation labels are placed so that they are not upside down, and are located at regular intervals along the contour line (see Figure 8–10b).



Line	Common Characteristics	AutoCAD Linetype
Index	0.014–0.028"/0.35–0.70 mm thickness, solid.	Continuous
Intermediate	0.010–0.014"/0.25–0.35 mm thickness, solid.	Continuous
Supplementary	0.010–0.014"/0.25–0.35 mm thickness, short dashes.	DASHED or HIDDEN

(a)



(b)

Figure 8-10. (a) Types of contour lines. Contour line labeling should be on index contours, placed at regular intervals, and should not appear upside down. (b) A portion of the Shady Valley, Tennessee-Virginia quadrangle map.

(Quadrangle map courtesy of the U.S. Geological Survey)

Intermediate Contours

Intermediate contours, also known as **minor contours**, are the four contour lines between index contours. Intermediate contours represent the intervals of elevation between the index lines. The first intermediate contour above the 450' index contour in Figure 8-10a,

for example, depicts a 460' elevation. Intermediate contours are usually thin, solid or dashed lines. Intermediate contours are normally not labeled but can be if necessary based on the scale and function of the map.

Supplementary Contours

A **supplementary contour** is a contour line used when the normal contour interval is too large to clearly illustrate significant topographic features on land with a gentle slope. Supplementary contours are generally not as common as index and intermediate contours, and are usually given the value of half the contour interval. Supplementary contours are usually thin, dashed lines. The supplementary contour in Figure 8–10a, for example, represents a 475' elevation.

Determining Contour Line Values

When constructing contour maps, you assign values to index contours based on the elevation in reference to the specified vertical datum. As explained in Chapter 6, a **vertical datum** provides the zero elevation reference for elevations of surfaces and features on the Earth. A geodetic vertical datum is the principle datum used to express land elevations and to provide vertical survey control. The current vertical datum in the United States is the North American Vertical Datum of 1988 (NAVD 88). Figure 8–11 provides examples of index contour values at a variety of contour intervals. The first index contour is at the vertical datum and has a value of zero (0) ft. elevation. Next, there are four intermediate contours, and the fifth line is an index contour.

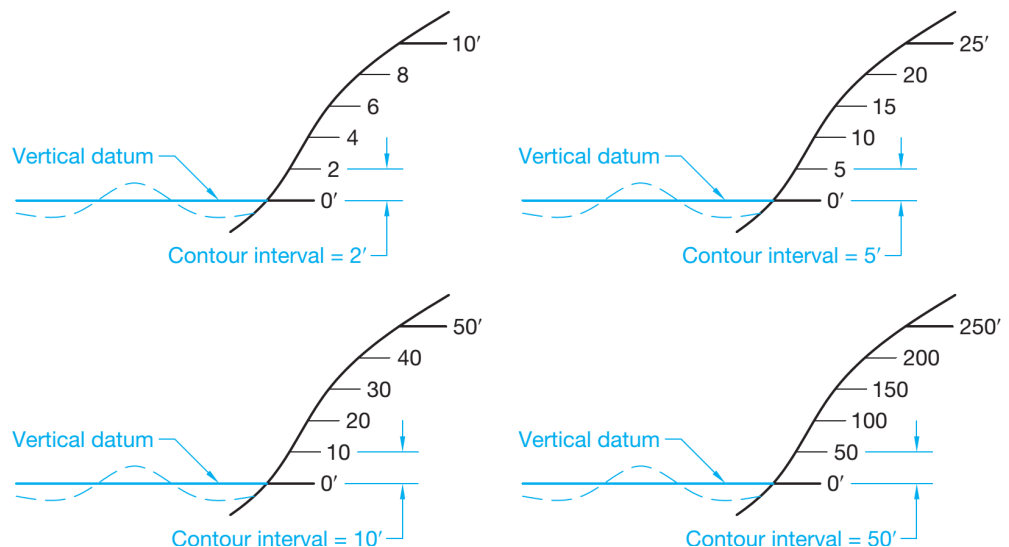


Figure 8–11. Every fifth line is an index contour, and the contour interval determines the value of the index.

Note: The AIA CAD Layer Guidelines include layer names with major and minor groups for topographic features such as -TOPO-MAJR for index contours and -TOPO-MINR for intermediate contours.

Plotting Contour Lines

Surveys provide an accurate view of the land by establishing the positions and elevations of points. The survey data is then used to plot contour lines on a map. The following information provides a valuable introduction to laying out a contour map. You will explore the techniques used to locate survey points on a map and interpolate, or estimate, the location of contours between survey points. These techniques are useful when using manual CADD tools with software such as AutoCAD. Importing a survey point file into software such as AutoCAD Civil 3D or Bentley Systems Power GEOPAK enables you to generate and display contour lines on a digital terrain model (DTM) at any contour interval and from any viewpoint. You will learn more about automated methods of plotting contour lines with CADD software later in this chapter.

Control Point Surveys

A **control point survey** is one method of establishing elevations for use in contour mapping. Figure 8–12 shows an example of the basic steps required in the contour mapping process. First, surveyors establish, plot, and label control points (see Figure 8–12a). Control points specify the positions and elevations of prominent features on the landscape. Next, a contour interval is chosen. The contour interval depends on the purpose of the map and the elevation differential within the map. Contour lines are then drawn to connect points of equal elevation (see Figure 8–12b). The elevations between control points may not be an even number. As a result, the mapper must interpolate between control points to find the even number. **Interpolation** is the process of inserting missing values between given numbers.

Interpolating Contour Lines by Estimation

You may be required to interpolate when plotting contour lines from survey field notes. One option is to interpolate contour lines by estimation, though typically a surveyor or mapper with experience should apply this method. Inserting missing values can be accomplished with a certain amount of accuracy if you understand the following basic steps:

Step 1: Establish elevations at stream junctions. For example, in Figure 8–13a, determine the elevation of the stream junction at point C given the elevations at points A and B. Take measurements to find that C is two-thirds of the distance

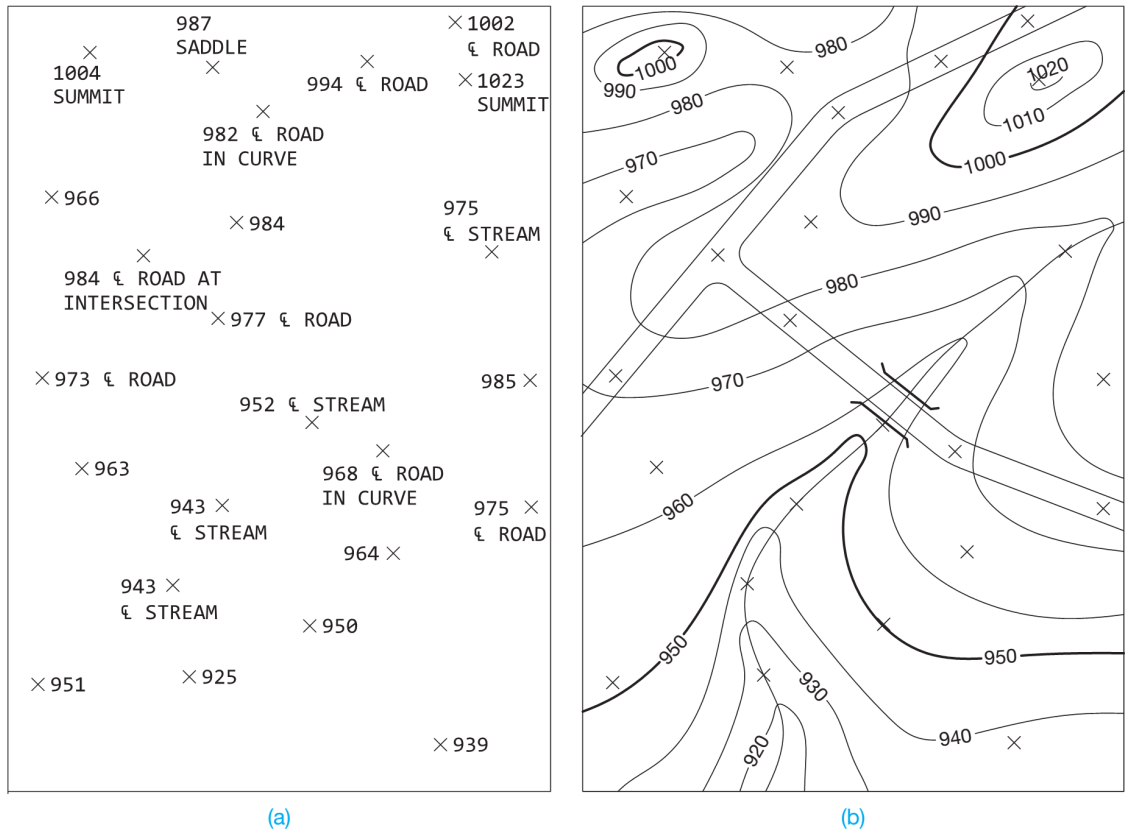


Figure 8-12. Plotting a contour map from a control point survey.

from A to B. The elevation difference between A and B is 60'. $\frac{2}{3}$ of 60' is 40'. As a result, the elevation of point C is 170'. Use this method to determine the elevation of the stream junction at point F.

Step 2: Locate points where contours cross streams. For example, in Figure 8-13b, locate the stream crossings of contour lines given a contour interval of 10' and spot elevations at points A, B, C, and D. The vertical elevation between points A and B is 20'. Divide the distance between A and B in half, to locate the 80' contour. The vertical distance between points B and C is 60'. Divide the line between B and C into six equal segments. The first new point from B is 100' in elevation. Use this method to determine the stream crossings of the contour lines between points B and D.

Step 3: Locate ridges using construction geometry. Areas of higher elevation usually separate streams except in swamps and marshes. For example, to locate the ridges shown in Figure 8-13c, draw a construction line beginning at the stream junction and connecting the highest elevation points between the two streams. Begin at stream junction A and draw a line through the 430', 458', and

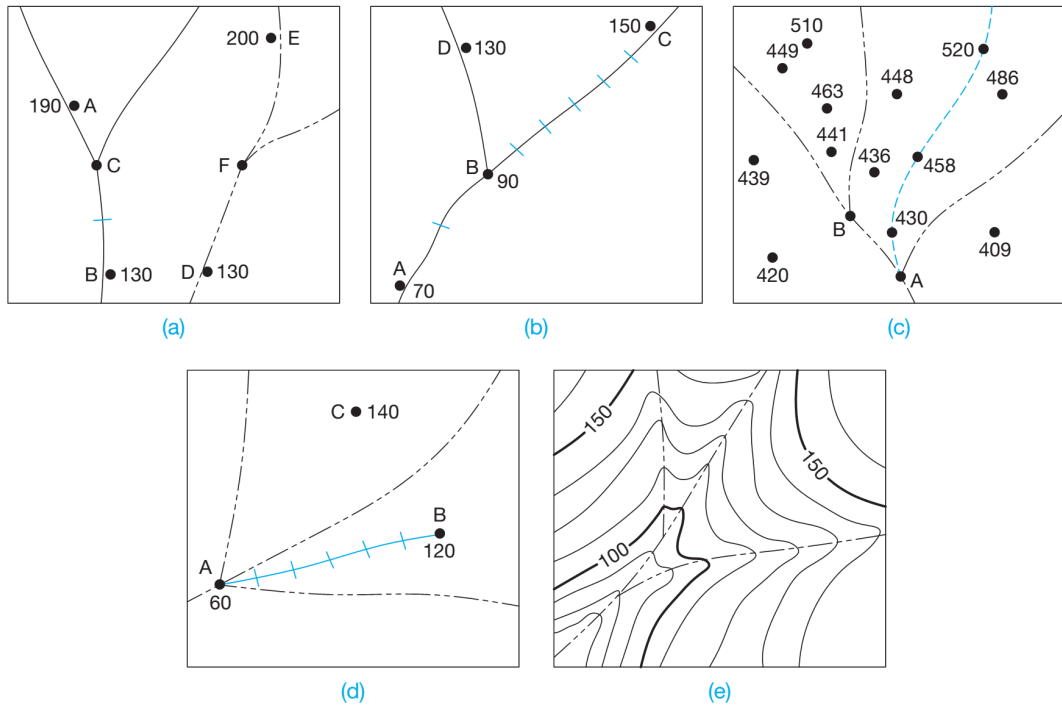


Figure 8-13. Methods of interpolating contour lines by estimation. The contour interval for each example is 10'.

520' elevation points. Repeat the process at stream junction B. Draw a line from B through the 441', 463', and 510' elevation points.

- Step 4:** Determine the points on ridge lines where contours cross. This step is performed in exactly the same manner as step 2. For example, in Figure 8-13d the space between point A and the spot elevation of 120' is 60'. Divide the line into six equal parts, as in step 2. Repeat the process to locate the contour crossings between points A and C.
- Step 5:** Connect the points of equal elevation with contour lines (see Figure 8-13e). Remember the characteristics of contour lines previously described as you plot contours.

Interpolating contour lines by estimation relies on using the uniform slope theory. The **uniform slope theory** is based on equal spacing of contours between known points. Figure 8-14 displays the basic concept of the uniform slope theory.

Mathematical Interpolation of Contour Lines

You can apply the theory of uniform slopes in a more exact manner by using the mathematical interpolation method. One method of mathematical interpolation is acceptable for control point surveys and requires that you use the scale of the map to measure the distance between two points. For example, in Figure 8-15, the measured

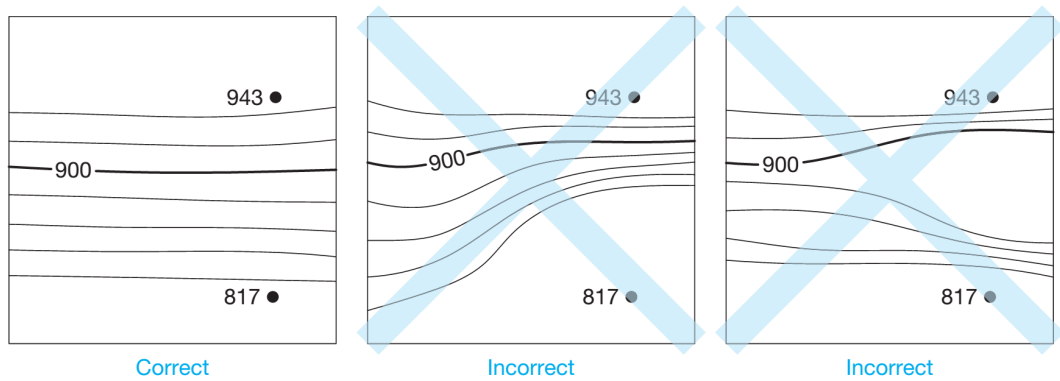
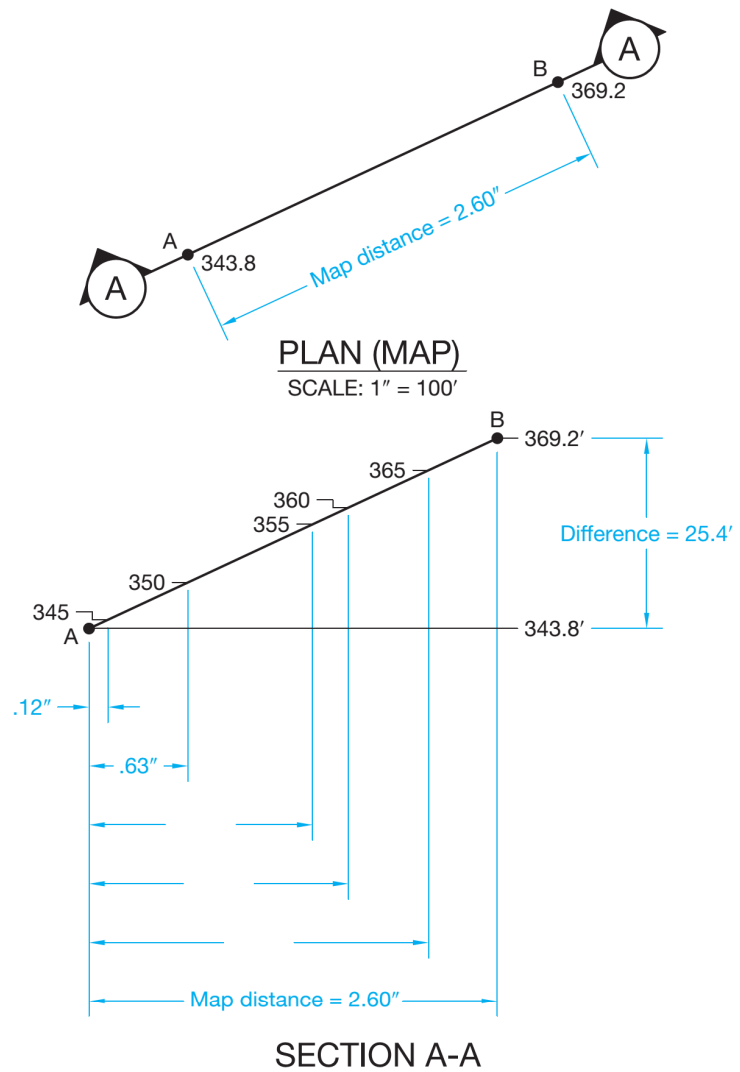


Figure 8-14. When interpolating contour lines using the uniform slope theory, space contours evenly as shown in the correct example.

Figure 8-15. Mathematical interpolation of contour lines allows you to calculate the distance between two points.



distance between points A and B on the plan, or map, is 2.6". This is a horizontal measurement on the plan and is not a measurement on a slope. The lower portion of Figure 8–15 is the section, or profile, cut along A–A in the plan view. The plan distance of 2.6" shown in the section view is the same horizontal measurement that is given in the plan view.

Next, calculate the difference in elevation between points A and B by subtracting the 343.8' elevation at point A from the 369.2' elevation at point B. The result is 25.4'. Now divide the plan distance of 2.6" by the difference in elevation, 25.4', to get the horizontal scale distance in inches per foot of vertical rise:

$$\frac{\text{Map distance}}{\text{Elevation difference}} = \text{inch/foot of vertical rise}$$

$$\frac{2.6''}{25.4'} = 0.102 \text{ inch/foot of vertical rise.}$$

If the contour interval is 5', the first contour above point A is 345'. The difference between this contour and point A is 1.2'. Multiply 1.2×0.102 , and the result is 0.12". This is the distance you measure from point A on the plan to find the 345' contour line.

Continue in this manner to locate the 350' contour on the plan. The difference between 350' and the 343.8' value of point A is 6.2'. Multiply 6.2' by 0.102, and the result is 0.63". This is the distance you measure from point A on the plan to find the 350' contour line. Find the remaining contours using this method and record your answers in the spaces provided in Figure 8–15.

Another method of mathematical interpolation uses the plan, or map, distance between two points to find a percent of slope. The slope can then be converted to a plan distance from the given elevation to contour lines. For example, in Figure 8–16, the elevation difference between points A and B is 25.4'. Divide 25.4' by the plan distance of 260':

$$25.4 \div 260 = 0.098$$

The result is a percent of slope of 0.098. Next, subtract the elevation of point A from the nearest contour, 345'. To solve for the distance from point A to the 345' contour, or x , divide 1.2' by 0.098:

$$0.098x = 1.2'$$

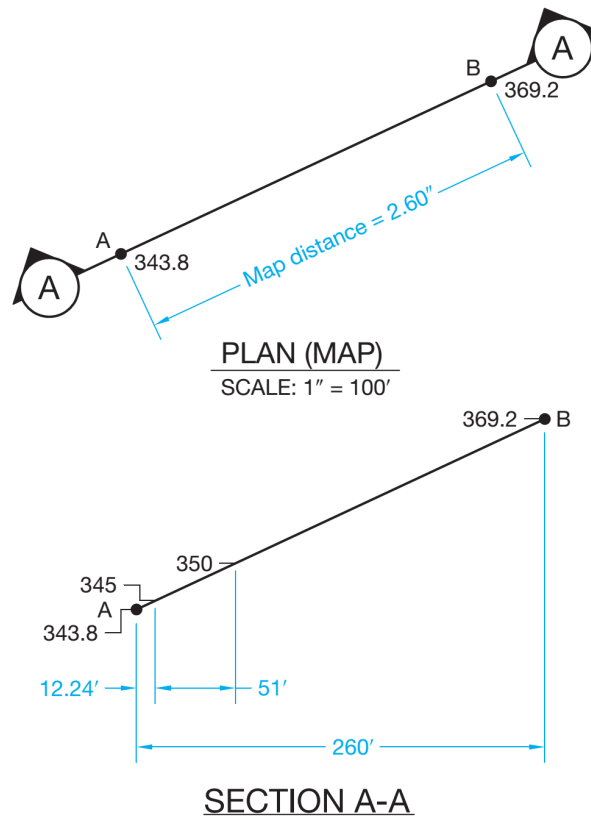
$$x = 12.24'$$

The value, 12.24', is the distance to measure on the map view from point A to find the 345' contour. Use this method to solve for the location of each additional contour from point A.

Grid Surveys

During a grid, or checkerboard, survey, a surveyor divides a plot of land into a grid. Stakes are driven into the ground at each grid intersection. Elevations at each stake are measured, recorded, and plotted on a grid at the required size. Figure 8–17a shows the initial grid layout. Additional stakes may be placed and recorded

Figure 8-16. The map distance between two points can be used to determine the percent of slope. The slope is converted to a distance between a given elevation and a contour line.



if significant elevation changes occur between grid intersections. The surveyor determines the size of the squares based on the land area, topography, and elevation differential. The vertical lines of the grid in Figure 8-17 are labeled with letters and are 20' apart. The horizontal lines, labeled 0+00, 0+20, 0+40, 0+60, and so on, are called stations. The stations are also 20' apart. The first number in the station label is hundreds of feet, and the second number to the right of the plus sign (+) is tens of feet. For example, the station number 5+45 is 5 hundreds and 45 tens, or 545' from the point of beginning.

The elevation of each grid intersection is recorded as shown in Figure 8-17b. To plot the elevations, first label all of the grid intersections with elevations (see Figure 8-17c). Next, connect the elevations with lines. Given the required contour interval, decide which elevation points to connect and when to interpolate between uneven elevation points (see Figure 8-17d). Figure 8-17e shows the finished contour map.

Interpolating Contours for Grid Surveys

A mathematical interpolation method can also be used to plot contours in a grid survey. The process uses the theory of uniform slopes and a formula with the following values: the amount over the whole foot contour of the highest point you are working from; the difference

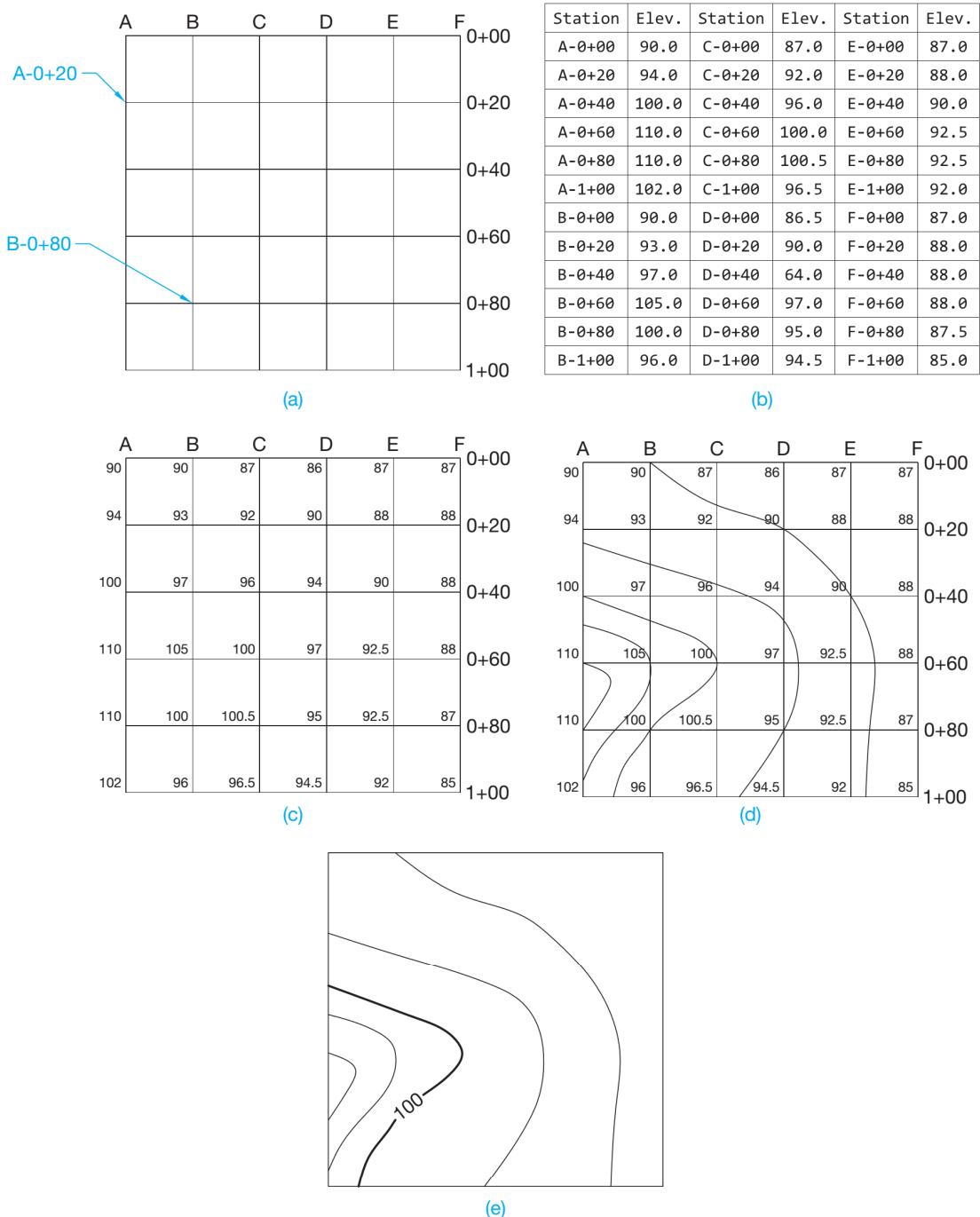


Figure 8-17. (a) For a grid survey, land is divided into a grid, or checkerboard, and labeled. (b) Survey notes specifying the elevation at each station. (c) All grid intersections are labeled. (d) Connect the elevations with curved lines or splines. (e) Completed contour map of grid survey.

in elevation between the point you are working from and the next lowest grid elevation; and the distance between the point you are working on and the next lowest grid intersection. The formula is written as follows:

$$\frac{\text{Amount above whole foot contour}}{\text{Difference in elevation}} \times \text{Distance between grid intersections}$$

Figure 8-18a shows examples of using the formula to calculate where contour lines will intersect sides 1, 2, 3, and 4 of a grid

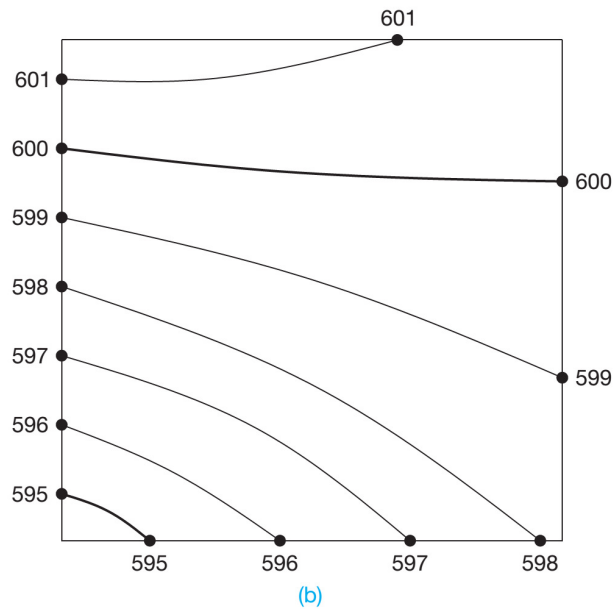
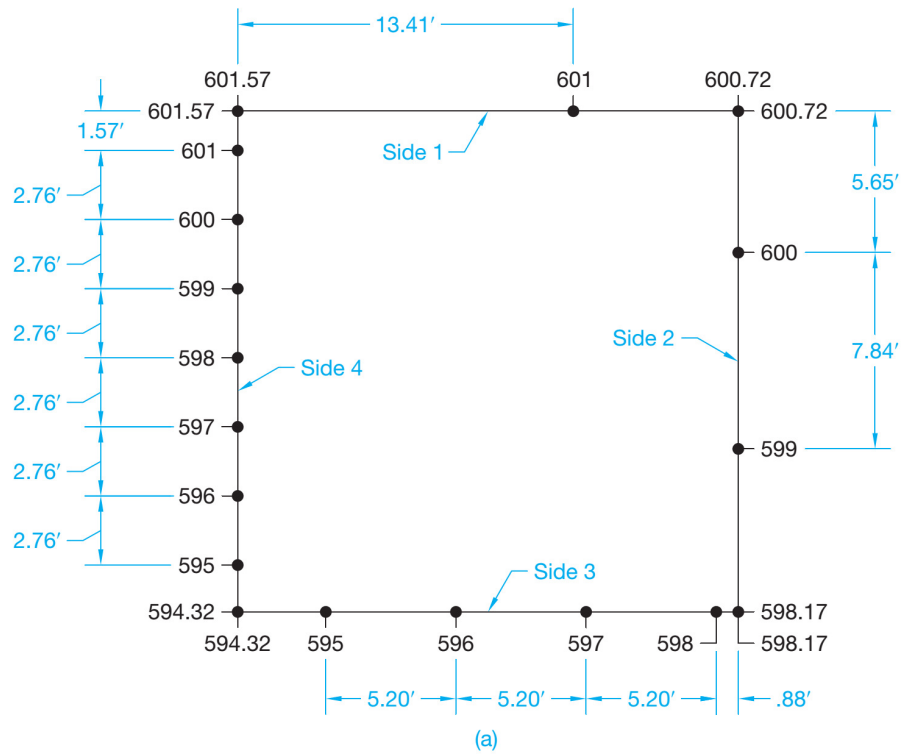


Figure 8-18. (a) The theory of uniform slopes used to calculate contours in a grid survey. (b) After locating elevation values on the grid, connect points of the same value to form contour lines.

cell. The examples begin calculating at the highest elevation of the two grid intersections. The 20' value in the formulas represents the 20' distance between grid intersections, or the length of each side.

Side 1: Calculate where the 601' contour will intersect side 1.

$$\frac{601.57 - 601}{601.57 - 600.72} = \frac{0.57}{0.85} = 0.67 \times 20' = 13.41'$$

In this formula, the numerator is the difference in elevation between 601.57' and 601', or 0.57'. The denominator is the difference in elevation between the two corners of side 1, 601.57' and 600.72', or 0.85'. Next, divide 0.57 by 0.85 to find the percentage of the distance of the 601' contour from the grid intersection 601.57'. The result is 0.67. This means that the 601' contour is 67% of the distance between grid intersection 601.57' and grid intersection 600.72'. To find the actual distance in feet, multiply 0.67 by 20' because the total length of side 1 is 20'. The answer is 13.41'. Measure 13.41' from the 601.57' point to find the 601' contour.

Side 2: Calculate where the 600' and 599' contours will intersect side 2.

$$\begin{aligned} \frac{600.72 - 600}{600.72 - 598.17} &= \frac{0.72}{2.55} = 0.28 \times 20' = 5.65' \\ 20' - 5.65' &= 14.35' \\ \frac{600 - 599}{600 - 598.17} &= \frac{1.00}{1.83} = 0.55 \times 14.35' = 7.84' \end{aligned}$$

Notice that only two calculations are required per side if more than two contours cross a side. The second formula calculates the horizontal distance for 1' of elevation. Therefore, no additional calculations are needed. The same process is used for the third and fourth sides.

Side 3: Calculate where the 598' through 595' contours will intersect side 3.

$$\begin{aligned} \frac{598.17 - 598}{598.17 - 594.32} &= \frac{0.17}{3.85} = 0.044 \times 20' = 0.88' \\ 20' - 0.88' &= 19.12' \\ \frac{598 - 597}{598 - 594.32} &= \frac{1.00}{3.68} = 0.27 \times 19.12' = 5.20' \end{aligned}$$

Side 4: Calculate where the 601' through 595' contours will fall at side 4.

$$\frac{601.57 - 601}{601.57 - 594.32} = \frac{0.57}{7.25} = 0.0786 \times 20' = 1.57'$$

$$20' - 1.57' = 18.43'$$

$$\frac{601 - 600}{601 - 594.32} = \frac{1.00}{6.68} = 0.15 \times 18.43' = 2.76'$$

After you locate the contour line elevations on the edges of the grid, connect points of the same value with contour lines (see Figure 8–18b).

Radial Surveys

A radial survey can be used to locate points for contour lines, property corners, structures, and natural features. Radial survey is also used when an instrument setup, or station, cannot be located on a point such as a property corner or section marker. Control points are established during a radial survey using a method called **radiation**, in which measurements are taken from a survey instrument located at a central point called a **transit station**. From this point, a series of angular and distance measurements are made to specific points. Readings such as this, taken from a transit station to specific control points, are called **side shots**.

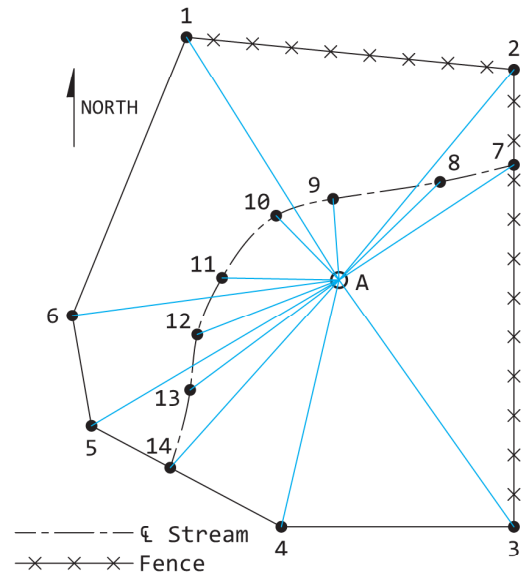
Additional transit stations are established if the area is too large to sufficiently map using a single transit station. When two transit stations are used, the line between the two transit stations is called a **baseline**. When more than two stations are used, the lines between the transit stations are called **transit lines**. Several transit lines can form an open or closed traverse, or a centerline survey.

During a radial survey, the surveyor records the azimuths and distances of each point from the transit station. The survey data can then be used to construct a contour map or property plat. Figure 8–19a shows an example of radial survey data used to map a piece of property, or plat. Any of the interpolation techniques previously described can be used to construct a contour map from a radial survey. Figure 8–19b shows the final plat plotted from the radial survey information. You will learn more about plats in Chapter 9.

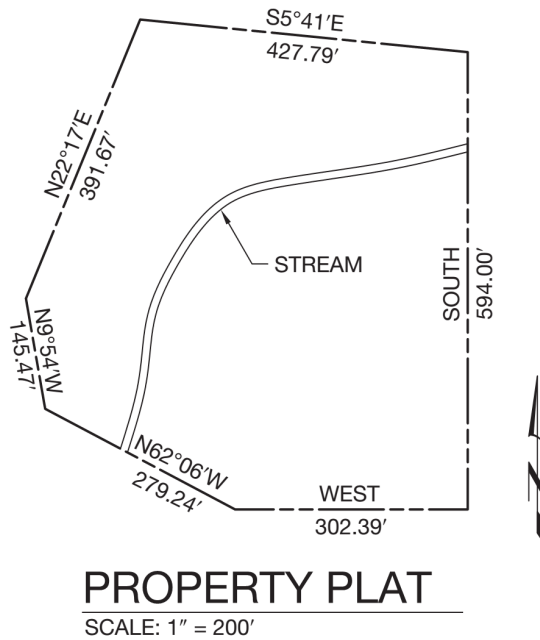
Contour Lines with Civil CADD

Civil engineering CADD software provides the capability to use data processed directly from surveying instruments such as an electronic total station to produce contour maps. A surveyor must be careful in the field to collect data that accurately represents all significant features of the site, such as edges of pavement, centerlines of roads, tops and toes of slopes, and the flow lines of ditches or streams. Information for each point is stored in a point file, which is then processed and imported into CADD software.

Station A		
North: 0° azimuth		
Point	Azimuth	Distance
1	327°52'	372.85
2	39°45'	355.57
3	144°40'	393.05
4	193°10'	329.29
5	239°27'	373.70
6	262°20'	349.95
7	56°44'	271.88
8	45°59'	182.69
9	355°45'	105.34
10	315°31'	116.68
11	271°02'	152.14
12	248°46'	197.76
13	233°27'	241.01
14	221°57'	328.28



(a)



(b)

Figure 8–19. (a) Radial survey data provides azimuths and distances, property corners, and additional control points. (b) The property plat drawn from the radial survey.

A triangulated irregular network (TIN) represents the topography data of a project from which a DTM can be extracted. A **TIN** is a surface model formed by triangulating a set of points. Each triangle represents a face on the surface. The elevations of the corners of

the face are known **quantities**. Software interpolates along the face edges and connects points of the same elevation along different edges to draw the contours at the desired contour interval. Once a surface has been built within a civil engineering CADD application, the software can be used to generate contours from the surface at any specified interval. Figure 8–20 shows an example of a 3-D DTM with contour lines.

Contours are typically represented as basic CADD geometry, such as lines or polylines, at the specified elevation. Contour line labels are established either automatically by the software according to a specified number of labels per contour, or can be added in a semi-automatic mode by manually indicating the desired locations for labels. Contour line labels can then be moved along the contour as necessary. Contour line labels reference text standards with predefined text characteristics. In some CADD applications, custom objects represent the contours with unique properties beyond those of standard geometry. Instead of lines or polylines, actual contour objects are created. Another approach to contours is to have contour lines appear as just another way to visualize a surface, without actually generating individual contour objects of any kind.

Each civil engineering CADD software program has its own method of producing a DTM and a set of contours in a drawing. However, the general process of creating a contour map is usually similar regardless of the specific software. For example, Figure 8–21 shows the four tabs in the Triangulate and Contour dialog box that

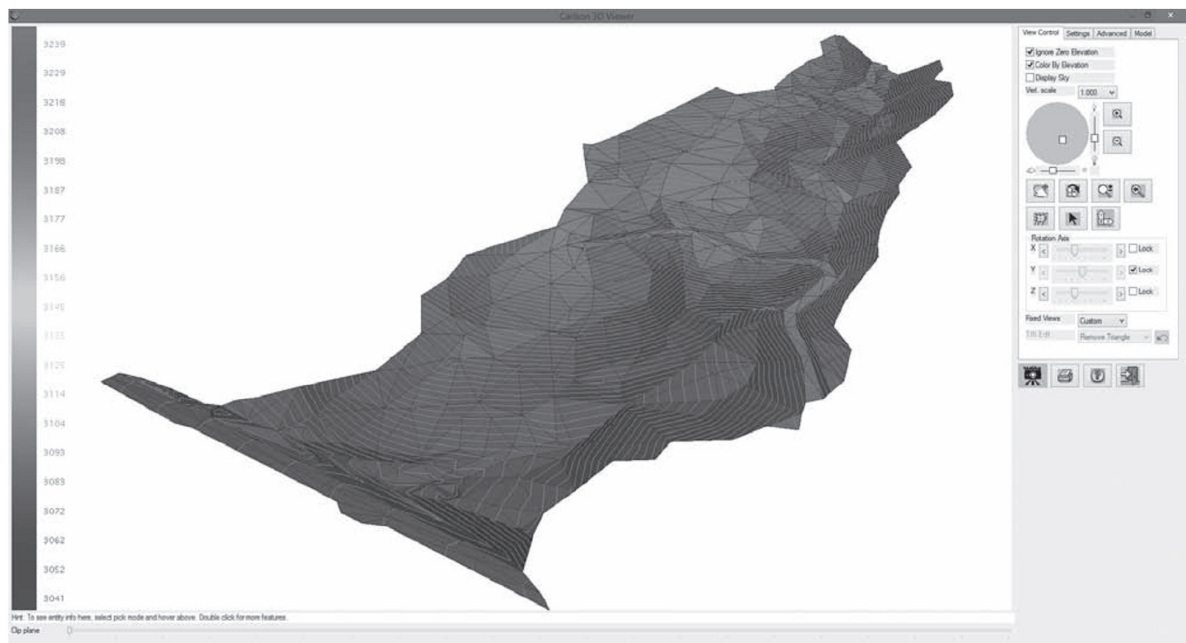
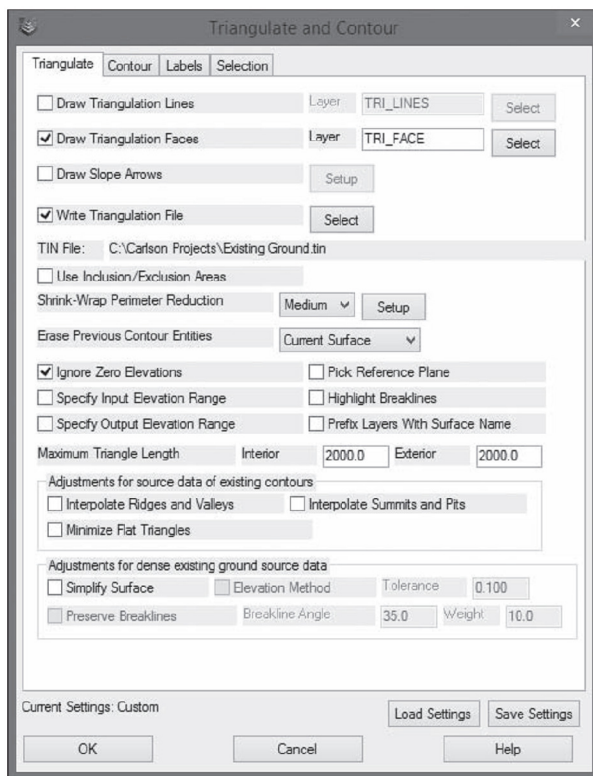
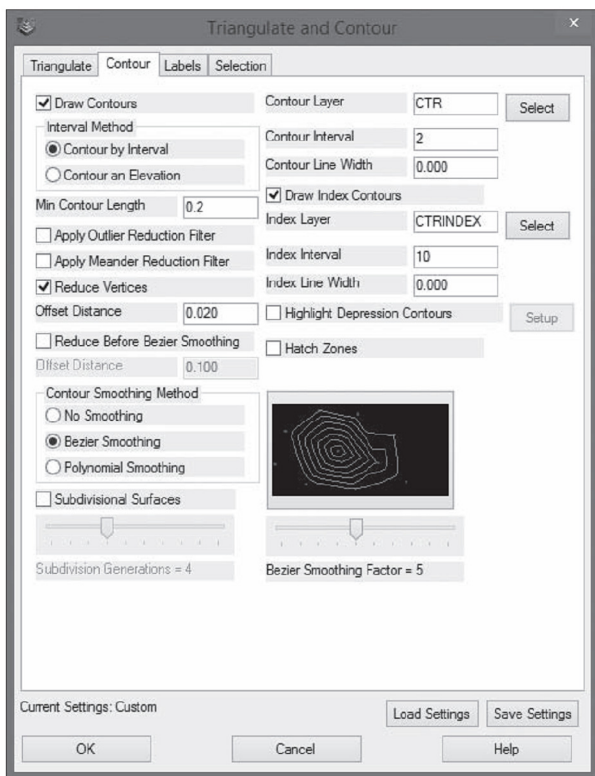


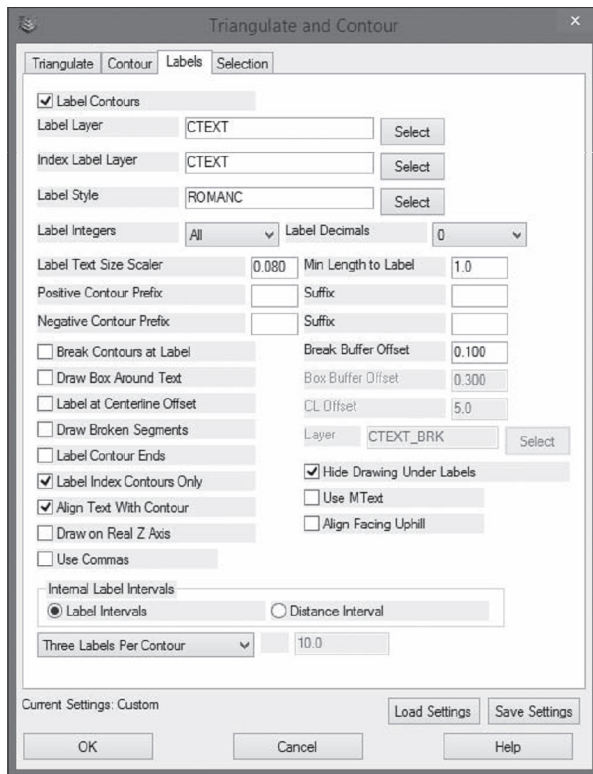
Figure 8–20. A 3-D digital terrain model (DTM) with contour lines.
(Courtesy of Carlson Software)



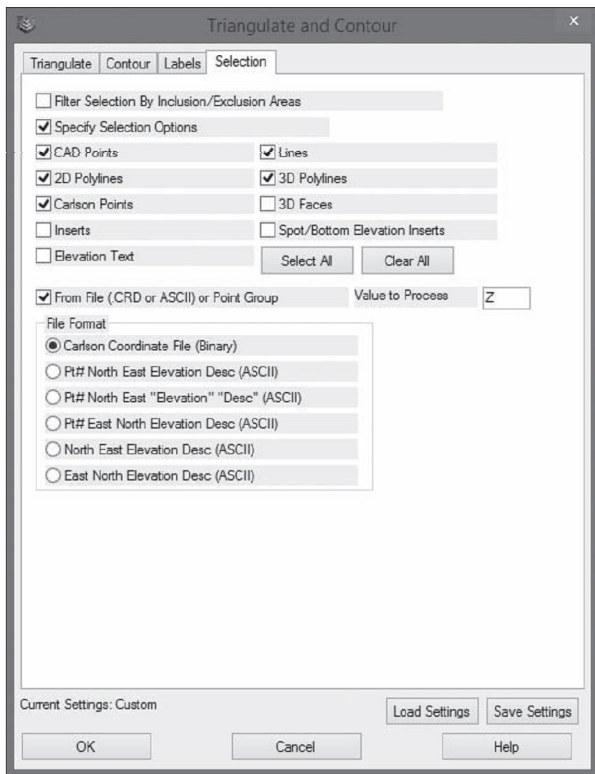
(a)



(b)



(c)



(d)

Figure 8–21. A Carlson Software example of how CADD software approaches contour mapping definition. (a) The Triangulate tab. (b) The Contour tab. (c) The Labels tab. (Courtesy Carlson Software)

are used to produce a contour map with Carlson Software. The process requires that you select a number of options in order to effectively display the finished contour map. Figure 8-21a shows options that control how the triangulated mesh is represented in the drawing and the naming and placement of the external TIN file. Figure 8-21b displays settings for controlling contour line features. This is where all aspects of the generated contours are controlled, including the interval and smoothing. Figure 8-21c displays options that specify the characteristics of the creation of contour line labels. Figure 8-21d shows options associated with the type of data used to generate the model surface. Figure 8-22 shows an example of a contour map that was created from field observations and generated from a raw data file.

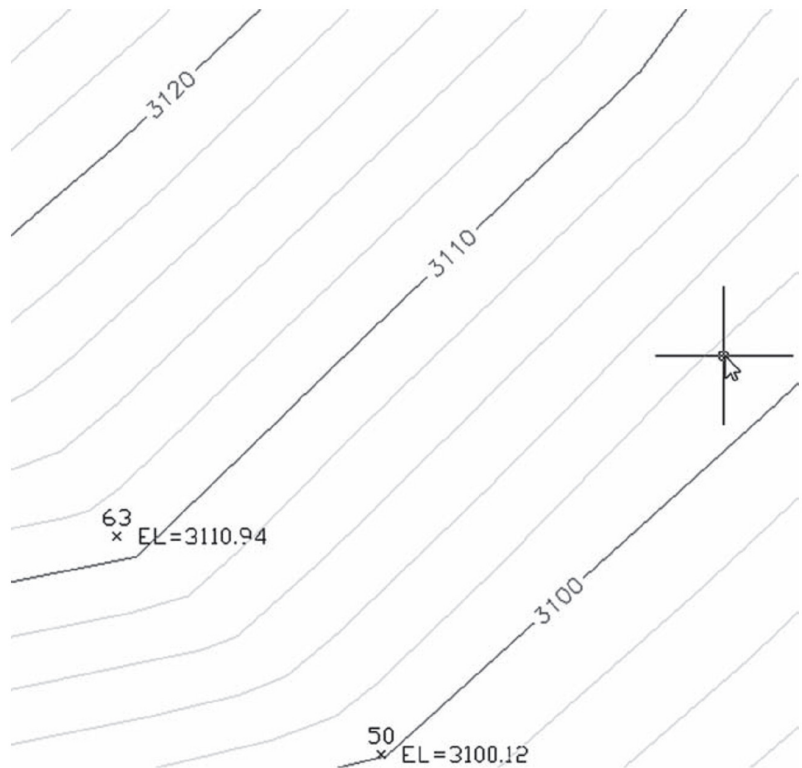


Figure 8-22. An example of a contour map generated from a raw data file.
(Courtesy Carlson Software)

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Define the following terms.

8-1 Contour line

8-2 Contour interval

8-3 Topographic map

8-4 Ridge

8-5 Saddle

Part 2

Sketch an example of how contour lines are used to represent the following characteristics.

8-6 Steep, uniform slope

8-7 Gentle, uniform slope

8-8 Concave slope

8-9 Convex slope

8-10 Ridge

8-11 Valley

8-12 Hilltop

8-13 Saddle

8-14 Volcanic crater

8-15 Cliff

Part 3

Choose the response that best describes each statement.

8-16 Every fifth contour line on a topographic map is known as what kind of contour line:

- a. Ridge
- b. Index
- c. Minor
- d. Upper

8-17 Contour line labeling identifies what value associated with the contour line:

- a. Scale
- b. Relief
- c. Elevation
- d. Length

8-18 The vertical distance between a point on a contour line and a point on the next closest contour line given a 10' contour interval is:

- a. 10'
- b. 15'
- c. 5'
- d. 20'

8-19 The type of survey that divides a plot of land into a checkerboard is known as a:

- a. Radial survey
- b. Control point survey
- c. Grid survey
- d. Geodetic survey

8-20 A triangulated irregular network (TIN) is commonly used to produce what item.

- a. Field point codes
- b. Survey data
- c. Material take off (MTO) sheet
- d. Digital terrain model (DTM)

PROBLEMS

Follow the specific instructions to complete each problem.

Part 1

Use proper methods of contour line interpolation and the specified contour interval to establish contour lines for the following problems. Label all index contours.

P8-1 See Figure P8-1. 10' contour interval. Go www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 8-1.dwg file to reference point data.

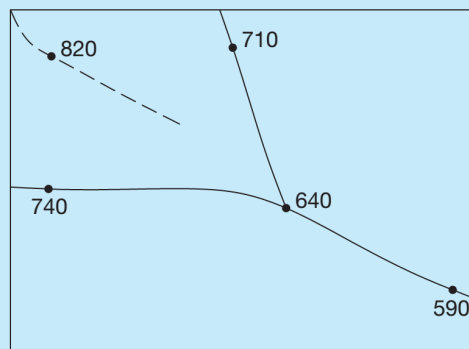


Figure P8-1.

P8-2 See Figure P8-2. 20' contour interval. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 8-2.dwg file to reference point data.

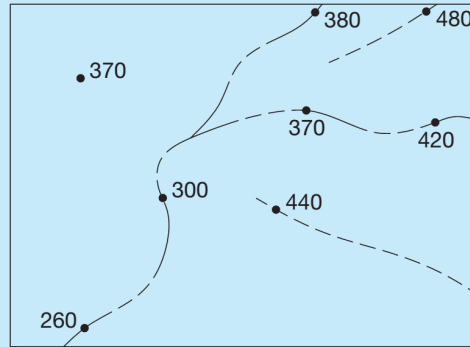


Figure P8-2.

P8-3 See Figure P8-3. 10' contour interval. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 8-3.dwg file to reference point data.

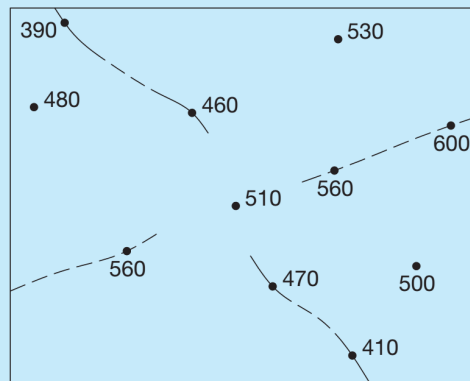


Figure P8-3.

Part 2

The following problems provide important practice in the layout of survey data and the creation of contour maps using manual methods. Draw contour lines according to the following instructions for each problem. Use proper methods of contour line interpolation and the specified contour interval. Use appropriate line-weights to represent each type of contour line. Label all index contours, and use a 1/8" plotted text height for all labels, notes, and dimensions. Include a north arrow and graphic scale when appropriate.

P8-4 Given the survey data shown in Figure P8-4, establish contour lines at a 5' contour interval. Label the roads, driveway, and other features. Plot the drawing at 1" = 100' scale on an appropriate sheet size. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 8-4.dwg file to reference point data.

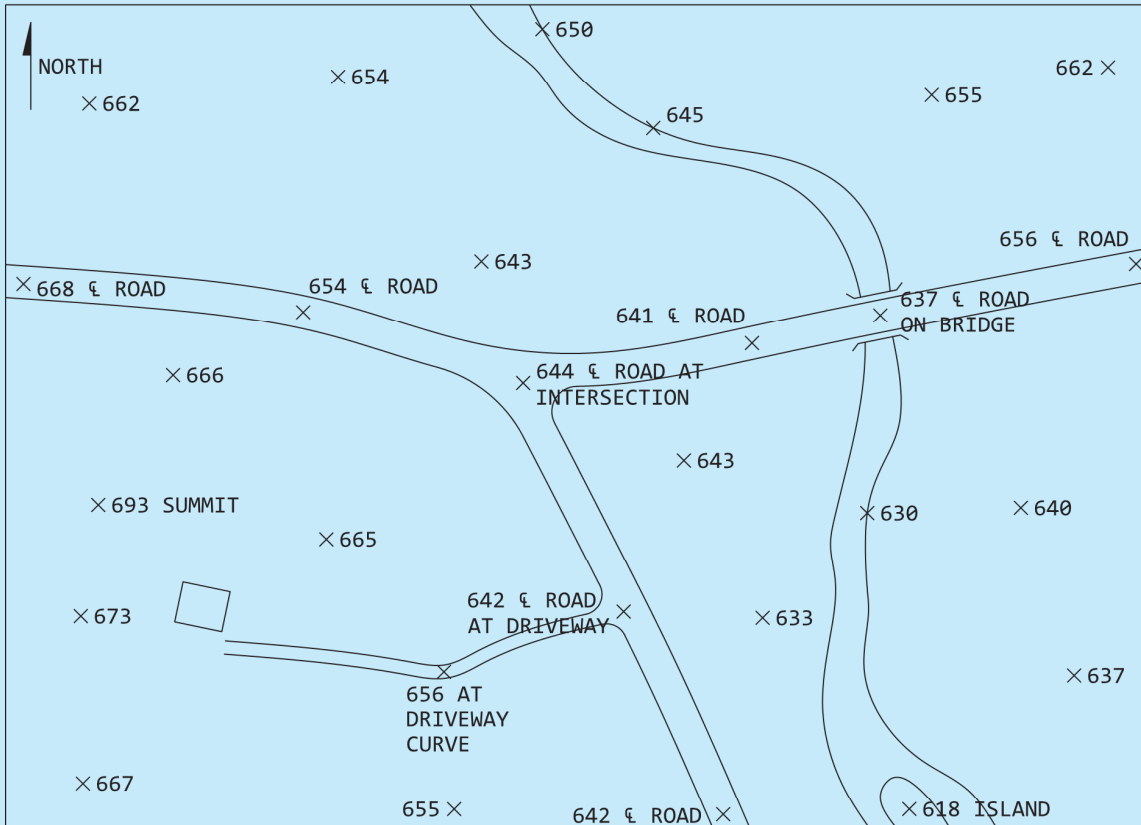


Figure P8-4.

P8-5 Use the survey data given in the grid shown in Figure P8-5 to plot contour lines at a 10' contour interval. Plot the final contour map at a 1" = 100' scale on an architectural C size sheet. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 8-5.dwg file to reference point data.

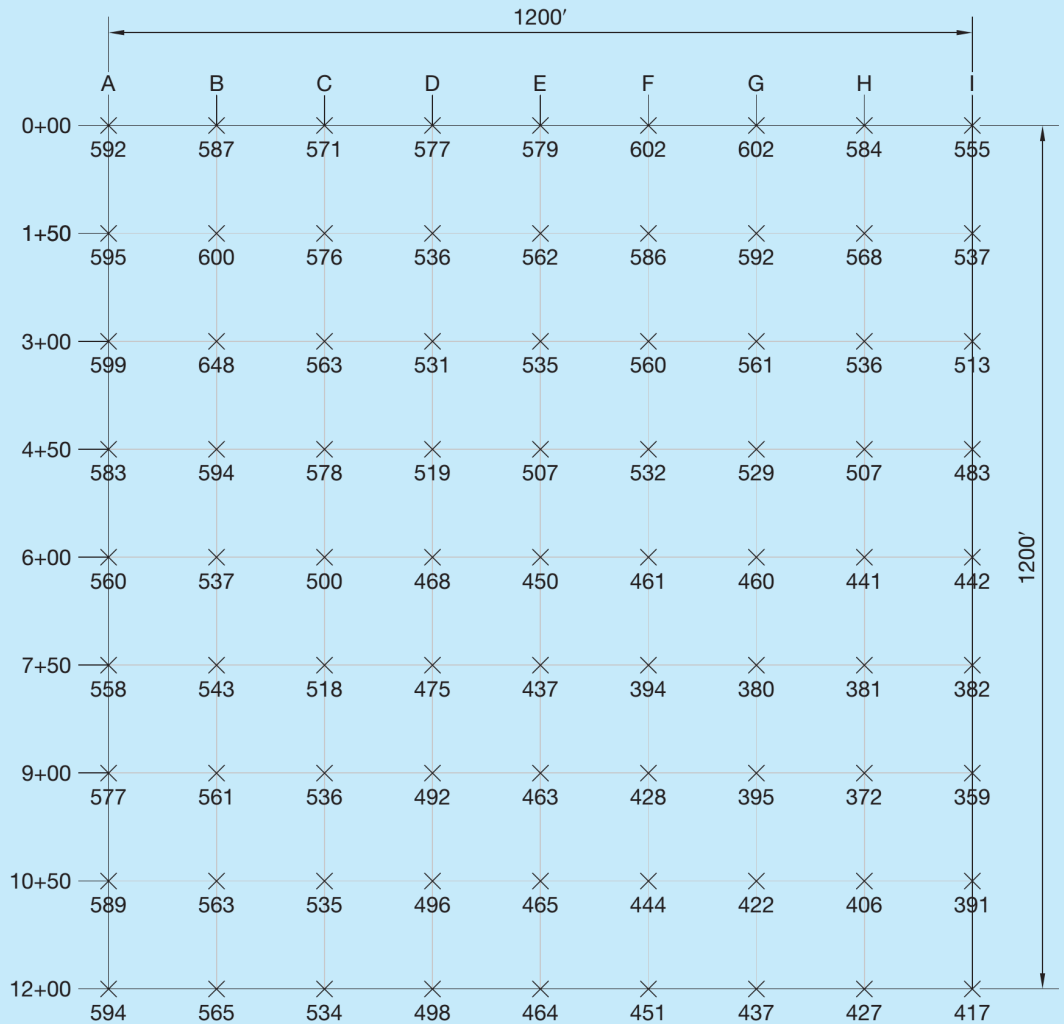


Figure P8-5.

P8-6 Given the survey data shown in Figure P8-6, draw a contour map using a 5' contour interval. Label all features. Include a north arrow and graphic scale. Plot the drawing at 1" = 20' scale on an appropriate sheet size. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 8-6.dwg file to reference point data.

P8-7 Given the survey data shown in Figure P8-7, draw a contour map using a 1' contour interval. Show and label all control points and features indicated in the field notes. Plot the drawing at an appropriate scale on an appropriate sheet size.

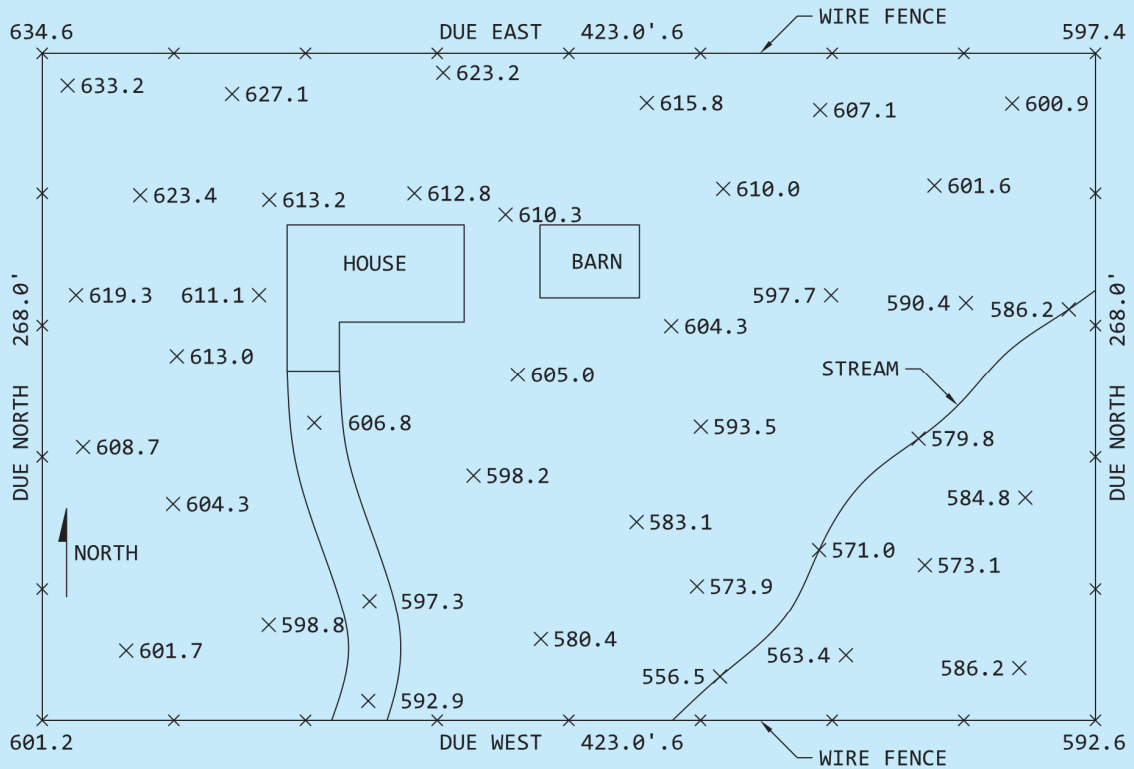
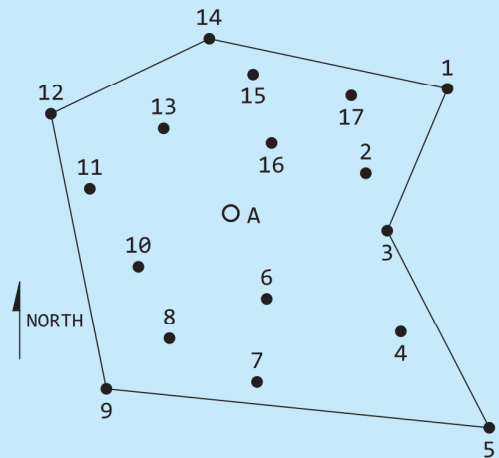


Figure P8-6.

Figure P8-7.

Station A			
North: 0° azimuth			
Point	Azimuth	Distance	Elevation
1	60°10'	268.73	793.2
2	73°35'	151.47	805.1
3	96°22'	169.34	806.8
4	124°52'	222.94	807.3
5	129°42'	361.39	802.7
6	157°11'	99.73	810.5
7	171°10'	183.94	806.2
8	206°03'	149.98	804.6
9	215°17'	231.62	800.3
10	239°57'	114.73	804.1
11	279°47'	153.80	799.2
12	298°51'	220.79	802.6
13	321°34'	116.02	805.0
14	353°02'	189.43	807.6
15	09°09'	151.30	801.2
16	30°16'	87.09	805.4
17	45°43'	181.04	799.1
A			812.4



- P8-8** Draw the property plat shown in Figure 8-19. Add contour lines using the survey data shown in Figure P8-8. The points correspond to the points in the Figure 8-19 field notes. Use a 2' contour interval. Plot the drawing at an appropriate scale on an appropriate sheet size.

Figure P8-8.

Station A			
North: 0° azimuth			
Point	Elevation	Point	Elevation
A	421.2	8	413.6
1	423.5	9	409.1
2	418.9	10	407.9
3	437.3	11	401.3
4	426.4	12	394.6
5	389.7	13	386.5
6	412.5	14	372.8
7	416.2		

- P8-9** A second survey of the site used in Problem P8-8 produced the data shown in Figure P8-9. Use the new survey to revise the map drawn in Problem P8-8.

Figure P8-9.

Station A			
North: 0° azimuth			
Point	Azimuth	Distance	Elevation
15	20°50'	228.75	418.3
16	344°59'	197.30	419.6
17	302°48'	282.61	416.7
18	291°10'	200.73	410.2
19	271°20'	271.39	411.9
20	250°11'	276.97	406.0
21	204°02'	204.65	414.7
22	173°33'	116.33	423.5
23	149°15'	246.61	428.1
24	113°35'	248.07	427.0
25	78°40'	123.11	412.8

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CHAPTER

9

Site Plans

Learning Objectives

After completing this chapter, you will be able to:

- Define plan views and identify types of site plans.
- Specify site plan requirements.
- Define terms related to site plans and legal descriptions.
- Interpret and write legal descriptions.
- Draw site plans from existing drawings, engineering sketches, and written information.
- Review a legal description for accuracy.

Key Terms

Plan view
Plan
Site plan
Plot plan
Plot
Plat
Lots
Vicinity map
Project map
Subdivision
Zoning
Site analysis plan
Grading plans
Grading
Planned use development
Planned unit development (PUD)
Metes and bounds
Metes
Bounds
Monument
Lot and block
Public Land Survey System (PLSS)
Baseline
Principal meridian
Townships
Ranges
Section
Potable water
Slurry pipelines
Easement
Utility easement

(continued)

Key Terms (continued)

Public utility easement (PUE)	Septic tank	Firebreak
Domestic sewage	Sludge	Wildfire zones
Storm sewage	Effluent	Chord
Sanitary sewer	Soil absorption field	Delta angle
Manhole	Drainfield	Included angle
Manhole cover	Leach lines	Setbacks
Maintenance hole	Cesspools	
Storm sewer	All-weather	

A **plan view**, or **plan**, is a view of an area looking down on the area as projected onto a horizontal plane. A **site plan**, also known as a **plot plan**, **plot**, or **plat**, is a drawing that shows an accurate layout of a piece of land. Engineers and developers use site plans to map construction projects. A plot plan is often referred to as a site plan when it shows existing and/or proposed structures and construction features such as buildings, roads, curbs, driveways, walks, and utilities. The term plat can refer to one or more pieces of land, but is commonly associated with a group of individual properties, typically called **lots**. This chapter explains typical site plan requirements and layout techniques.

Plan Views

Plan views illustrate all aspects of a project such as property lines, roads, structures, utilities, and landscaping. A variety of plan drawings may be created depending on the size and complexity of a project. Maps and site plans are some of the first drawings created for a project. A **vicinity map** places a project site within a large area, such as several square miles, and provides an overview of the site relative to the surrounding area (see Figure 9–1). A vicinity map provides information about access to the site. A **project map** shows a construction site in relationship to the immediately surrounding area (see Figure 9–2). The site plan is drawn at a larger scale than the vicinity and project maps, and shows detailed construction information in plan view. Several site plans may be included in a set of drawings, each illustrating a specific element of the design or project requirement. Figure 9–3 shows an example of a site plan, or plat, for a subdivision. A **subdivision** is a tract of land divided into lots. Figure 9–4 shows an example of a residential site plan.

Site Plan Requirements

There are several applications for site plans. The purpose of each type of site plan can be different, although the characteristics of the drawings are often similar. States, cities, and/or counties have guidelines for the type of site plans required for a project. Evaluate local

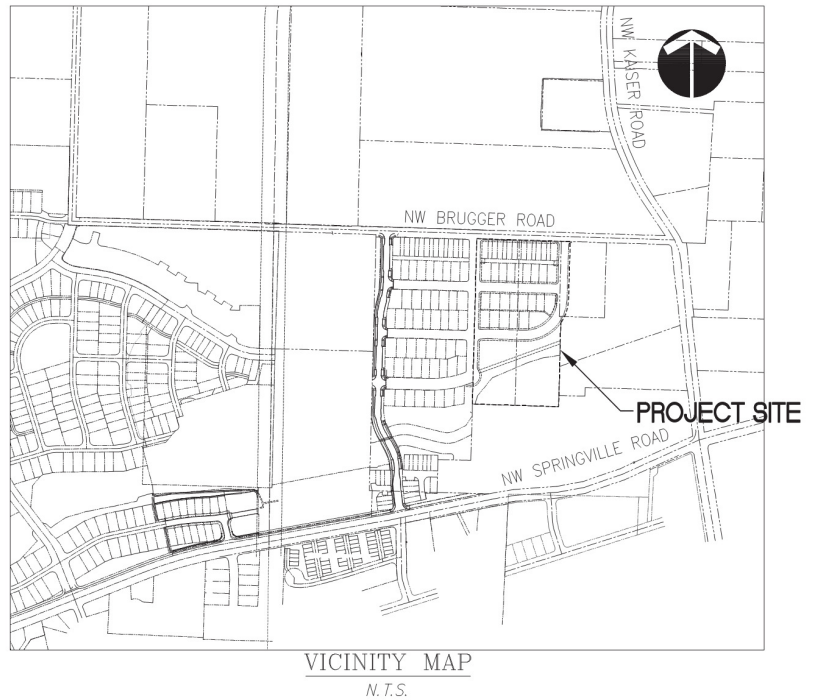


Figure 9-1. A vicinity map places a project site within a large area and provides an overview of the site relative to the surrounding area.
(Courtesy of Otak, Inc.)

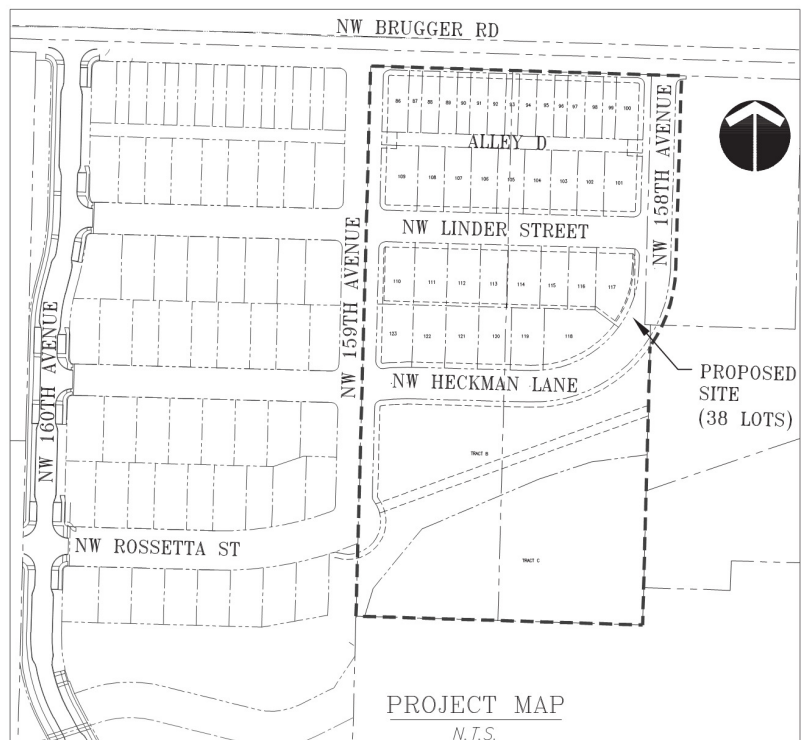


Figure 9-2. A project map shows a construction site in relationship to the immediately surrounding area.
(Courtesy of Otak, Inc.)

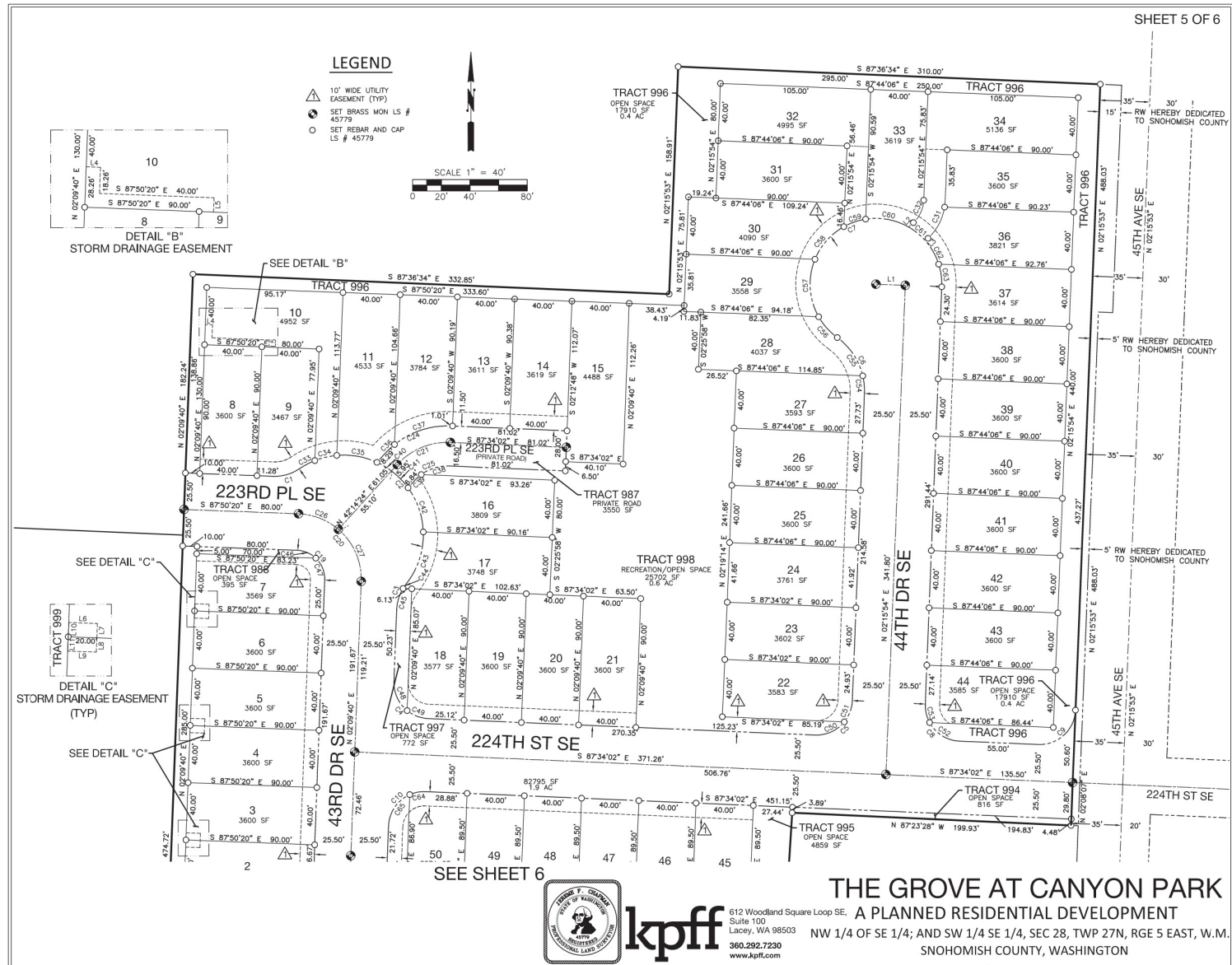


Figure 9-3. A portion of a subdivision plat required for the development of a residential housing subdivision.
(Courtesy of KPFF Consulting Engineers)

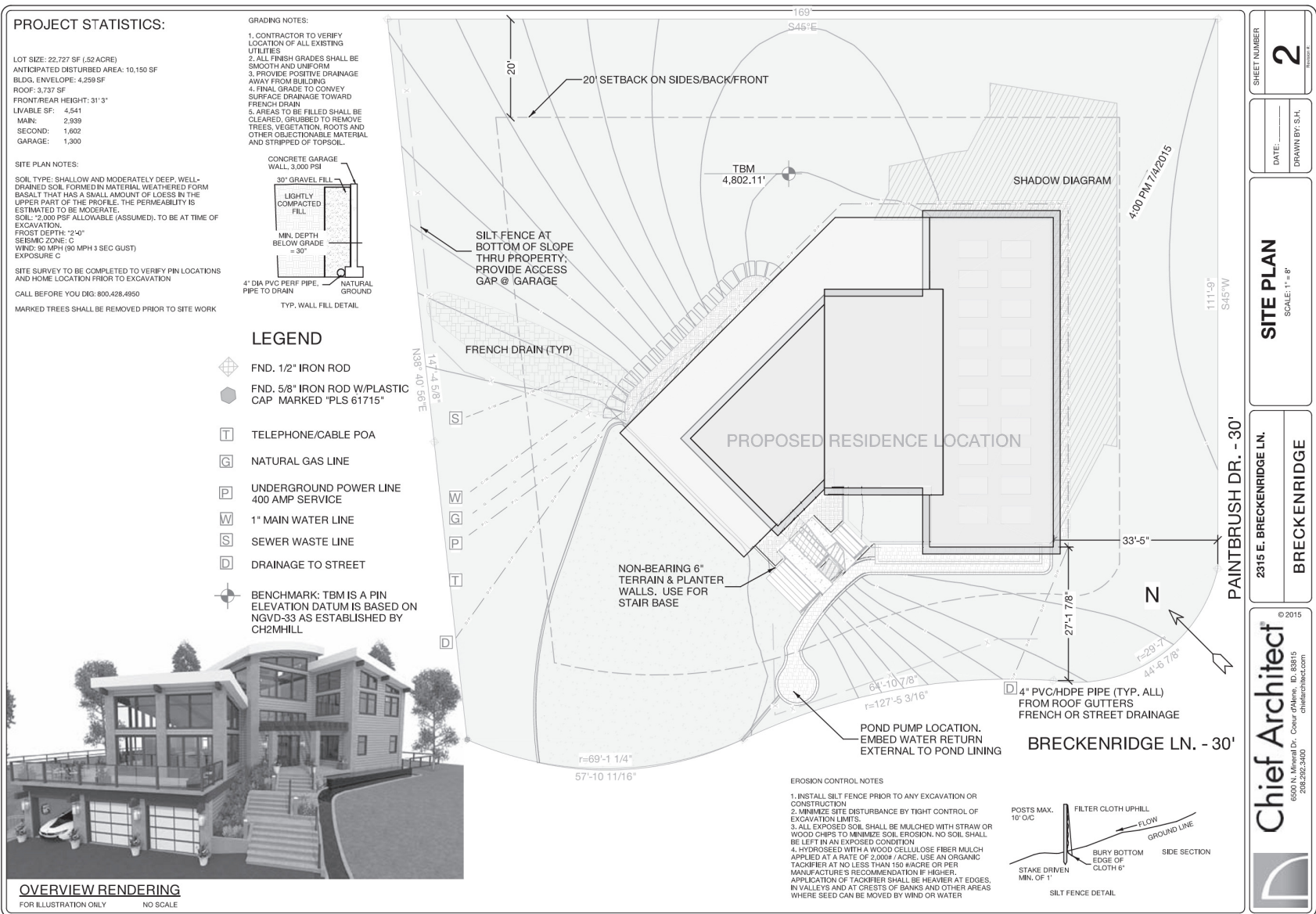


Figure 9-4. A residential building site plan.
 (Courtesy of Chief Architect Software)

guidelines before preparing a site plan for a specific purpose. Prepare the site plan in strict accordance with the requirements in order to receive acceptance. Building departments often provide a detailed checklist of requirements to submit a site plan.

A plot plan becomes a legal document containing an accurate drawing and a legal description of the land. Many items are necessary to make a plot plan a legal, working document. Building departments may require plot plans to be printed on a specific sheet size, such as an 11" × 17" (ANSI B) or 24" × 36" (architectural D) size sheet. The following is a list of possible site plan requirements. Site features such as water wells and trees on adjacent properties are often required. Use the information as a checklist for proper completion of a site plan.

- Vicinity map
- Legal description of the property
- Zoning designation
- Property lines, and property line dimensions and bearings
- Total square footage and/or acreage of the property
- Topography or the slope of the ground, including contour lines and/or ground elevations at lot corners, street centerlines, driveways, and floor elevations
- Existing and proposed roads
- Existing and proposed structures, including location dimensions from property lines and between structures
- Number of bedrooms and/or square footage of proposed dwellings
- Driveways, patios, decks, parking areas, and walkways
- Setbacks from all property lines
- Location of water well and/or water service line
- Location of water wells on adjacent properties
- Location of proposed natural gas and power lines
- Method of sewage disposal including the location of septic tank, drainfield, drainfield replacement area, and/or sewer lines
- Dimensions and spacing of soil absorption field, or leach lines
- Location of soil test holes required to analyze geological conditions, soil compaction, and soil absorption
- Location of rain drains, footing drains, and method of storm water disposal
- Drainage channels and direction of flow, and whether drainage is seasonal or year-round
- Easements
- Existing and proposed trees
- Legend
- Direction of north
- Drawing scale
- Contact information of the property owner, applicant, and engineer or surveyor
- Date the drawing was made
- Building permit application number

Note: It is not always necessary to show relief as contour lines. Sometimes only arrows are used to show direction of slope. Contour lines are drawn when required by local code; when required for design purposes; or when the land has unusual contours or drainage patterns, or is especially steep.

Site Analysis Plans

There are a variety of procedures and requirements for site development depending on local guidelines and zoning rules. **Zoning** is a system of land use planning and public restrictions applied by local governments. Zoning originates from the practice of separating one type of land use from another into mapped zones. Zoning typically divides land uses into groups, such as residential, commercial, industrial, farming, forests, and wetlands. Zoning can also regulate specific uses, such as building height and lot coverage.

In areas where zoning and building permit applications require a design review, a site-analysis plan can be required. A **site analysis plan** provides the basis for the proper design relationship of the proposed development to the site and to adjacent properties (see Figure 9–5). The degree of detail of the site analysis plan is generally appropriate to the scope of the proposed project. For example, larger, more complex projects typically require a site analysis plan with more information. In addition to many of the site plan requirements previously listed, a site analysis plan often displays slope shown by contour lines and/or cross sections, traffic patterns, and pedestrian patterns.

Grading Plans

Grading plans are construction drawings that generally show existing and proposed topography. **Grading** refers to the process of building a specific slope or level surface. Chapter 12 provides more information about grading. Figure 9–6 shows a detailed grading plan for a public utility and roadway improvement project. In the Figure 9–6 example, roadway features such as the edges of pavement and walkways are shown with elevations of critical points specified throughout. The thick, dashed line represents the extents of grading. Notice that the legend identifies symbols for existing and finished contours.

The grading plan shown in Figure 9–6 provides graded slopes to accommodate a smooth and gradual slope along the centerline of the roadway from the intersection of the roadway at a highway to the end of the roadway. The finished slope represents portions of material removed or added to establish the relationship of the proposed contour to the existing contour. Some grading plans also show a cross section, or profile, through the site at specified intervals or locations to evaluate the contour more fully. Chapter 11 explains profiles.

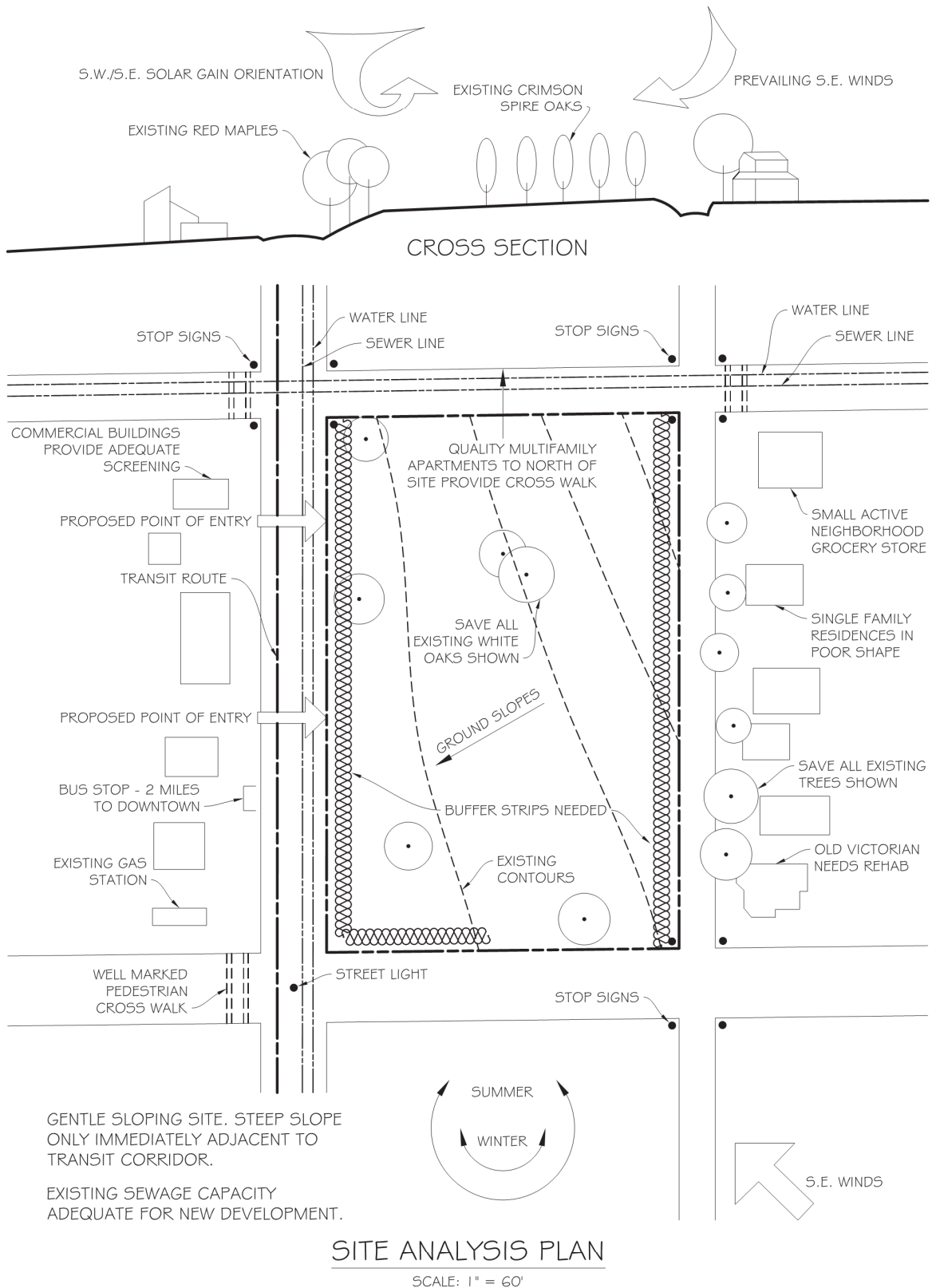


Figure 9-5. A site analysis plan.

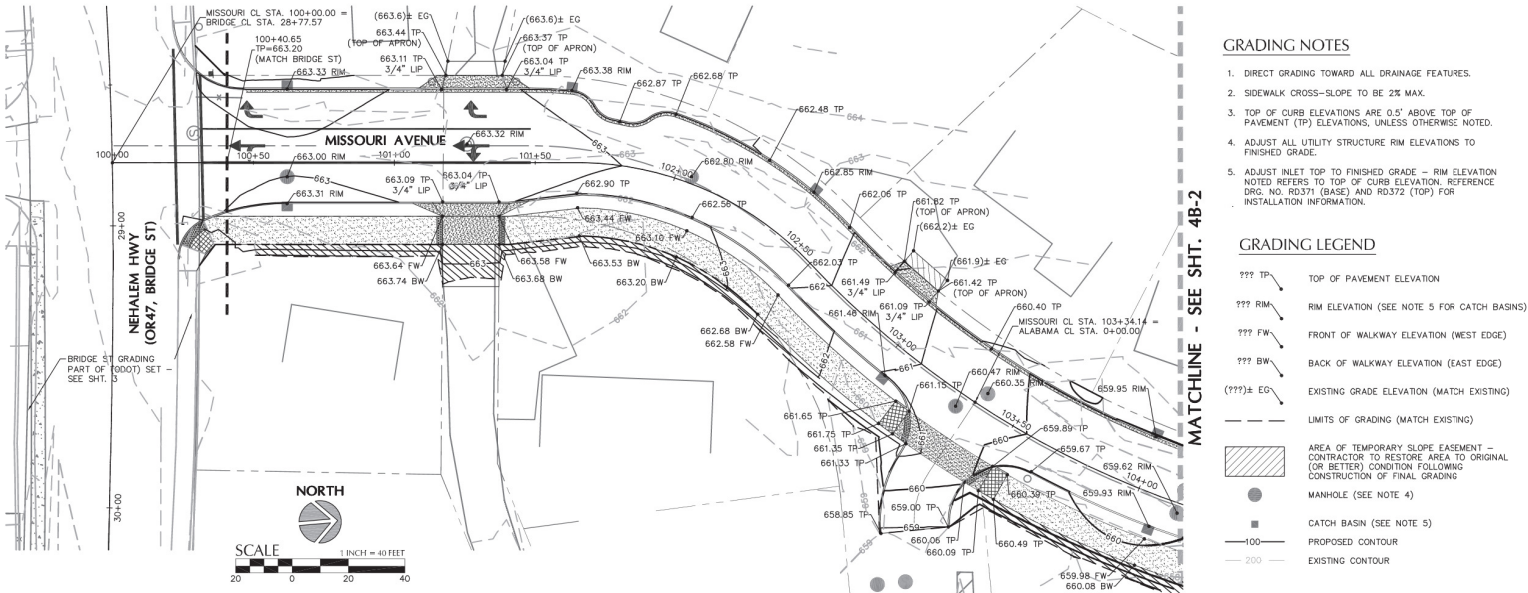


Figure 9-6. A detailed grading plan for a public utility and roadway improvement project.
(Courtesy of KPFF Consulting Engineers)

Subdivision Plans

Requirements for subdivision drawings vary, depending on local guidelines and zoning rules. Figure 9–3 shows an example of a site plan, or plat, for a subdivision. Some areas have guidelines for minor subdivisions with few sites that differ from major subdivisions with many sites. The local planning agency determines the size of minor and major subdivisions. A major subdivision can require more detailed plats than a minor subdivision. In addition to many of the site plan requirements previously listed, a subdivision plan often includes the following elements. Some of the items may be found on the plat or in a separate document.

- Gross acreage of property being subdivided or partitioned
- Name of the major partitions or subdivision
- Identification of each lot or parcel by number
- Existing and proposed streets, including name, direction of drainage, width, approximate grade, and radius of curves
- Legal access to subdivision or partition other than public road
- Name of water and sewer district
- Calculations justifying the proposed density
- Contour lines at 2' interval for slopes of 10% or less; 5' interval if slopes exceed 10%
- Areas to be offered for public dedication
- Contiguous property under the same ownership
- Boundaries of restricted areas
- Significant vegetative areas such as major wooded areas

Planned Unit Developments (PUDs)

A **planned use development** or **planned unit development (PUD)** allows zoning with mixed uses such as single- and multifamily homes, parks, schools, offices, small businesses, restaurants, and grocery stores. Figure 9–7 shows a basic PUD plan. The PUD model is a creative and flexible approach to land development that allows people to work and participate in activities without excessive traveling. In addition to many of the site plan requirements previously listed, a PUD plan often includes a land use summary and displays special spaces, such as recreational and open spaces, or other unique characteristics.

Describing and Locating Property

Each individual property must be completely described in a survey. A survey becomes the legal description that keeps your property separate from your neighbor's property. The legal description of the property is an important element of a site plan. This chapter explains the three typical ways of identifying property; metes and bounds, lot and block, and the Public Land Survey System (PLSS).

Metes and Bounds

Metes and bounds is a method of describing and locating property by measuring the length and bearings of property lines from a known starting point called a monument. **Metes** can be defined as

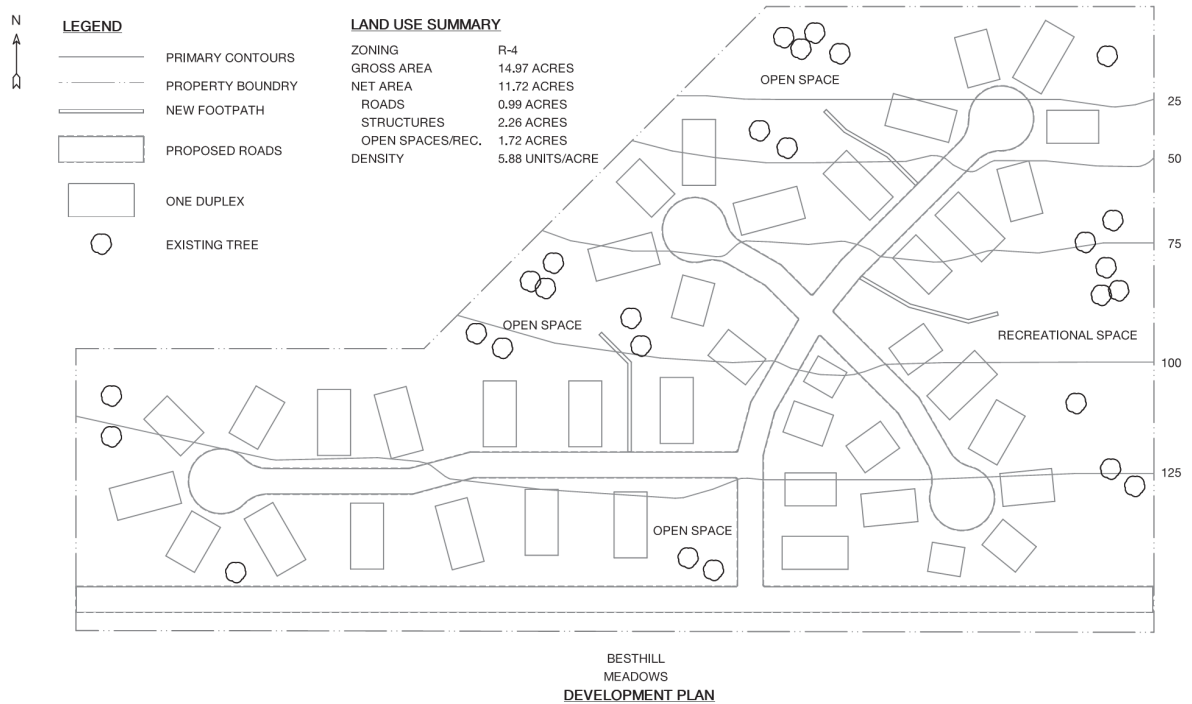


Figure 9-7. A basic example of a planned unit development (PUD) plan.
(Courtesy of Chief Architect Software)

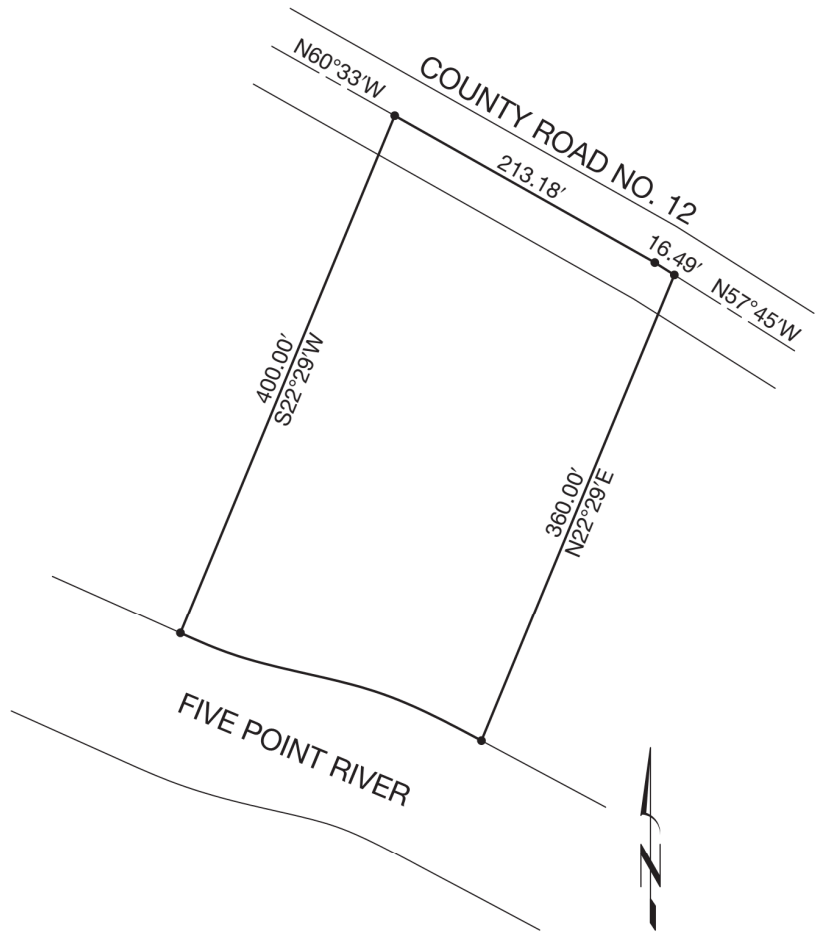
being measurements of features such as property lines expressed in units of feet, yards, rods, or meters. **Bounds** are boundaries, such as streams, streets, roads, or adjoining properties. The **monument**, or point of beginning (POB) of the system, is a fixed point such as a section corner, a rock, a tree, or an intersection of streets.

Figure 9-8 shows the metes and bounds for a tract of land. The distances and bearings of property lines are examples of metes. The road and river are examples of bounds. Figure 9-9 illustrates metes and bounds applied to a subdivision plat. The distances and bearings of property lines are examples of metes. The adjoining properties and street between properties are examples of bounds.

The metes and bounds system is often used to describe irregularly shaped plats and, while used in all areas of the country, it is the primary method of describing plats in states east of the Mississippi River. The following is a legal description using metes and bounds:

BEGINNING at the intersection of the centerline of W. Powell Boulevard, formerly Powell Valley Road and the centerline of S.W. Cathey Road; thence running East along the centerline of W. Powell Boulevard 184 feet; thence South on a line parallel with S.W. Cathey Road, 200 feet; thence West on a line parallel with W. Powell Boulevard, 184 feet; thence North along the centerline of S.W. Cathey Road to the place of beginning; EXCEPTING therefrom, however, the rights of the public in and to that portion of the herein described property lying within the limits of W. Powell Boulevard and S.W. Cathey Road.

Figure 9-8. Metes and bounds used to describe and locate a tract of land.



Lot and Block

Lot and block is a method of describing land by referring to a recorded plat, the lot number, the county, and the state. A legal lot and block must be filed with the county clerk or recorder as part of a subdivision plat (see Figure 9-10).

The lot and block system is commonly used to describe small units of property in a subdivision. The exact boundaries of the subdivision can be described using the metes and bounds or rectangular system. The rectangular system is explained later in this chapter. For example, the property lines of the lots in the small subdivision shown in Figure 9-10 are established using metes and bounds; but the lots can additionally be identified with a lot and block system.

The following is an example of a lot and block legal description:

Lot 7, Block 135, Oregon City Subdivision, City of Oregon City, Clackamas County, State of Oregon.

Public Land Survey System (PLSS)

The **PLSS** is a rectangular system for describing land in the United States, developed by the U.S. Bureau of Land Management (BLM).



Figure 9-10. The lot and block system used to describe small units of property in a subdivision.

Basic Reference Lines

Each large portion of the PLSS is a single great survey that consumes as much of one parallel of latitude and one meridian of longitude as possible. The initial point of each great survey is where these two basic reference lines cross. The location of basic reference lines is determined astronomically. The east–west parallel is called the **baseline**, and the north–south meridian perpendicular to the baseline is called the **principal meridian**. There are 37 principal meridians in the PLSS (see Figure 9–11).

Initially, each principal meridian was numbered. However, the numbering stopped with the sixth principal meridian, which passes Nebraska, Kansas, and Oklahoma. The rest of the 31 sets of standard lines took on local names. For example, in Montana, the public land surveys use the Montana meridian for the principal meridian.

Townships

Townships are a rectangular grid system of surveys that originate from, and measure north, south, east, and west of the intersection of each baseline and principal meridian. A township is 36 square miles in size. Townships are defined by an arrangement of horizontal rows and vertical columns. The horizontal rows, or tiers, north and south from the baseline are also called **townships**. For example, a township in the third tier north of the baseline is named “Township 3 North,” abbreviated “T3N.” Similarly, the third tier south of the baseline is named

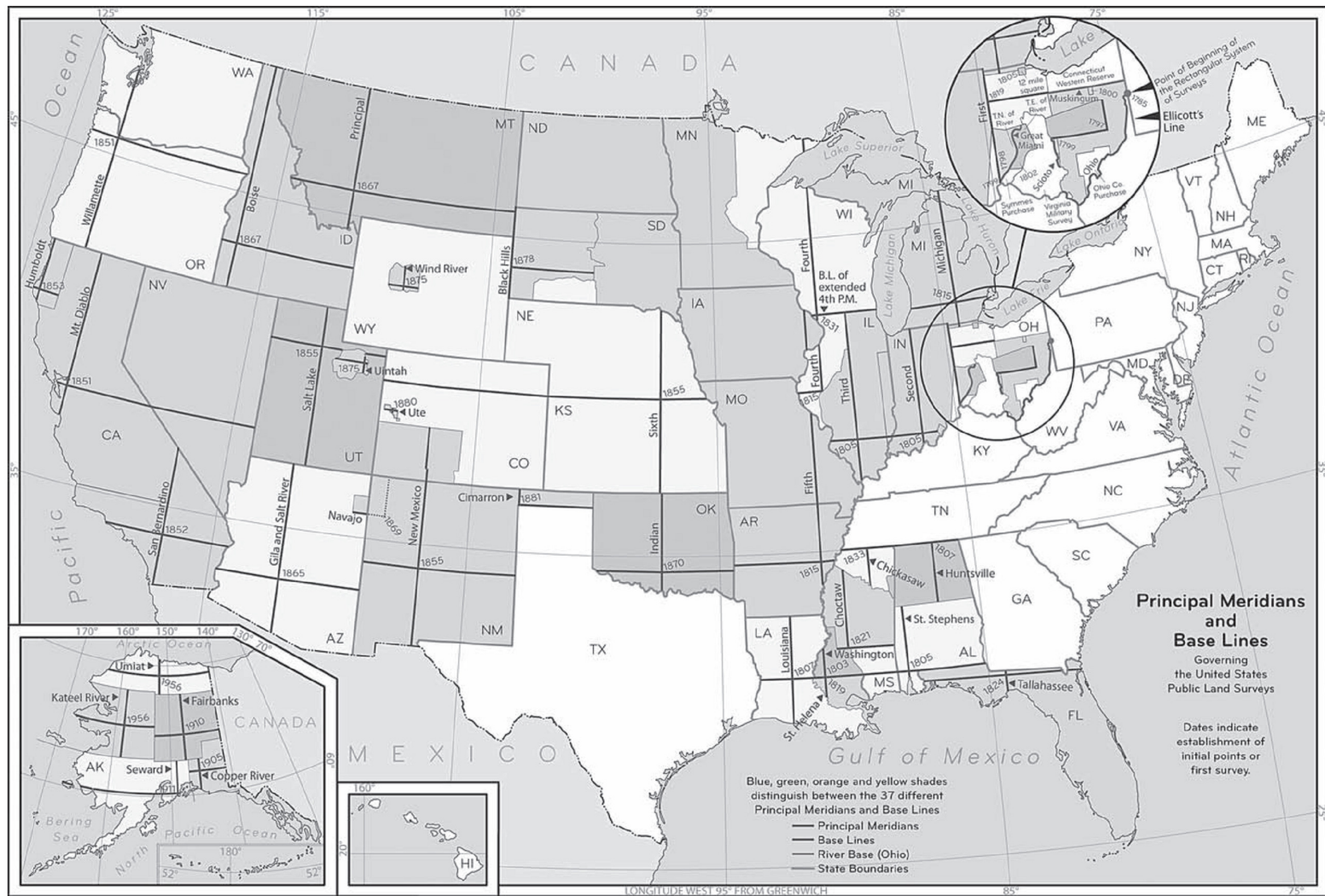


Figure 9-11. The baselines and principal meridians of the Public Land Survey System (PLSS).
(Courtesy of the U.S. Bureau of Land Management)

“T3S.” The vertical columns east and west from the principal meridian are called **ranges**. For example, a township in the second range east of a principal meridian is “Range 2 East,” abbreviated “R2E.”

When you put townships and ranges together, the township in the third tier north of the baseline and in the second range east of the principal meridian is “Township 3 North Range 2 East,” abbreviated “T3N, R2E.” Figure 9–12 illustrates the arrangement of townships about the two reference lines. The tiers number as far north and south and ranges number as far east and west as the great public land survey in which they are located.

Sections

A township is a square with sides approximately 6 mi. long. At each mile along the 6 mi. sides of a township, a line cuts across, forming a checkerboard of 36 squares, each a mile square. These squares are called sections. A **section** is a parcel of land, approximately 1 sq. mi., containing 640 acres. There are 43,560 sq. ft. in an acre.

Sections are numbered 1 to 36, beginning at the northeast corner of the township and going across from right to left, then left to right, and right to left, until all 36 squares or sections are numbered. Sections always start numbering with 1 in the upper right corner, and 36 is always in the lower right corner. Figure 9–13 shows the division of a township into sections and how the sections are numbered in each township. Section number five, identified in Figure 9–13 for example, is labeled “Section Five,” abbreviated “sec5.” The following is a legal description of a section includes the state, principal meridian

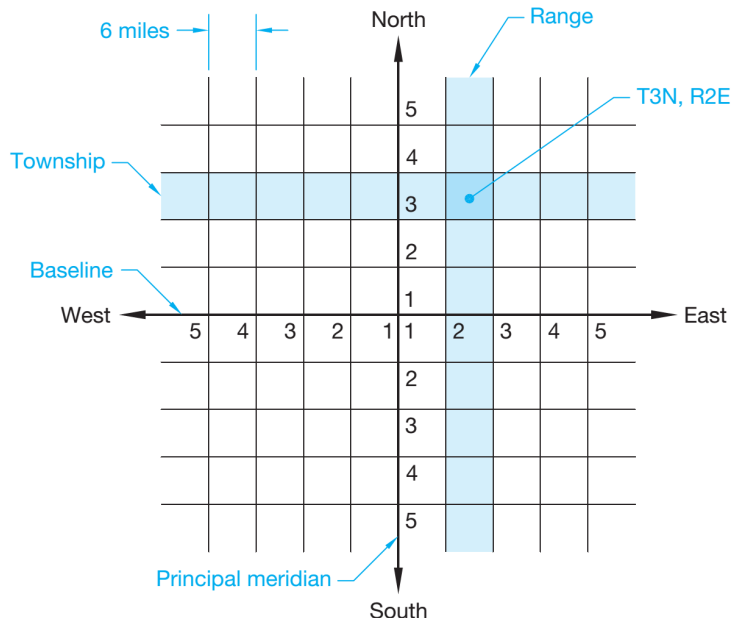
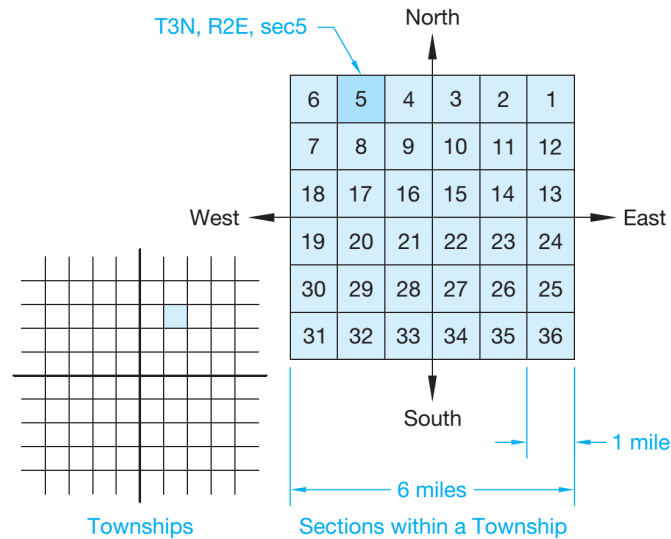


Figure 9–12. Arrangement of townships about the baseline and principal meridian.

Figure 9-13. Correct method of numbering sections within a township.



name, township and range designations with directions, and the section number: Idaho, Boise Principal Meridian T3N, R2E, sec5.

Subdivision of Sections

Figure 9-14 illustrates typical subdivisions of a section. Each section can be subdivided into quarter sections. These are sometimes called corners; for example, the “Northwest Corner of Section 16” is abbreviated “NW 1/4 of Sec16.” A quarter section can be further divided into quarter-quarters. For example, “NW 1/4, NW 1/4 of Sec36.” Figure 9-14 shows further subdivisions of a quarter-quarter. The smallest subdivision shown in Figure 9-14 is 10 acres. However, even smaller subdivisions can be made, such as a residential subdivision of lots less than an acre in size.

In a written description of a portion of land, the smallest portion is written first, followed by the next larger portion, and so on. In Figure 9-14, the smallest portions are two 10 acre subdivisions. Notice that the description begins with the smallest division and progresses to the largest; for example, “SW 1/4, SW 1/4, SW 1/4” shown in the lower left corner in Figure 9-14.

The Complete Description

The description of a small subdivision must include its relationship with the township and relate to the reference lines of the great survey. Remember that a complete description begins with the smallest division and progresses to the largest. An example of a legal description reads like this:

The SW 1/4, SE 1/4 of Section 5 in Township 3 North, Range 2 East of the Boise Meridian, all being in Ada County, Idaho.

The following legal description demonstrates that a complete description of real property can include all three types of descriptions in combination. This example uses the rectangular system to identify

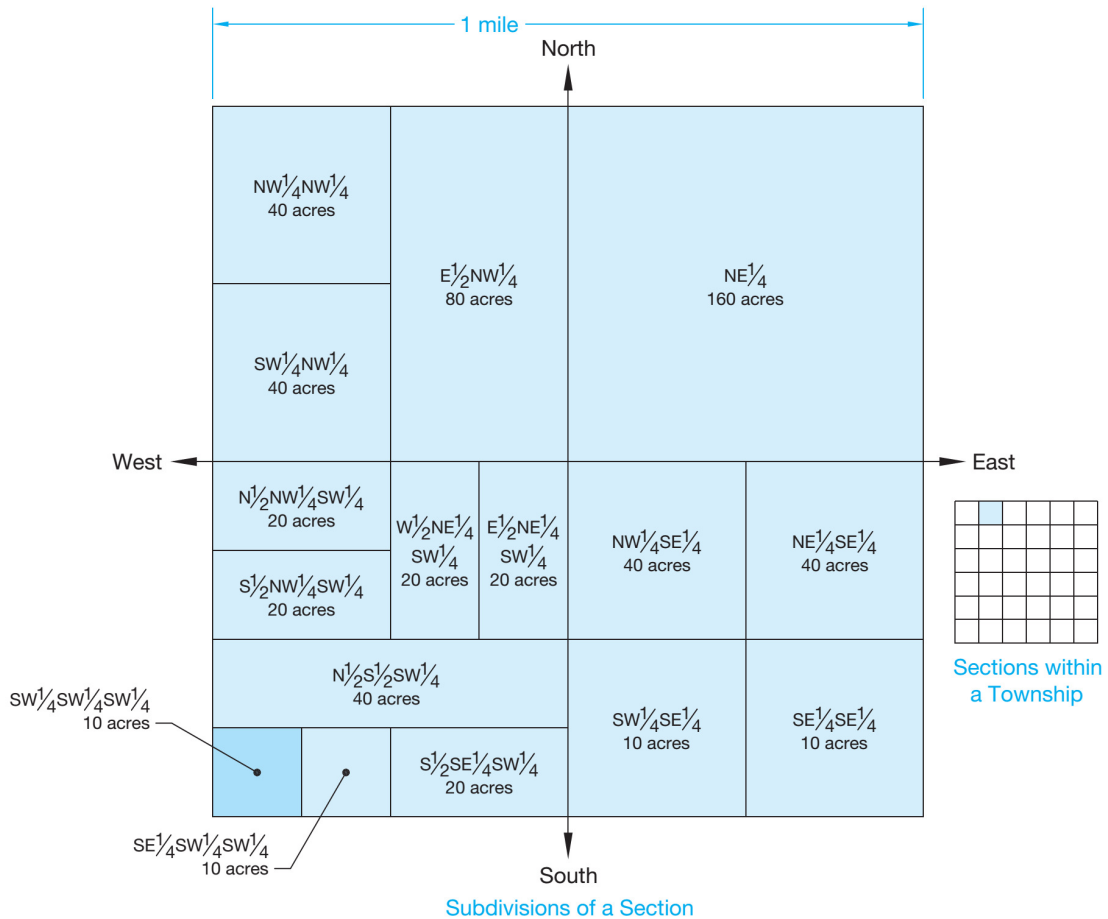


Figure 9-14. Typical subdivisions of a section.

the POB, metes and bounds to describe the boundary lines, and a lot and block description as an alternate description:

Part of the Stephen Walker D.L.C. No. 52 in Sec.13 T. 2 S. R. 1 E., of the Willamette Meridian, in the County of Clackamas and State of Oregon, described as follows:

Beginning at the one-quarter corner on the North line of said Section 13; thence East 111.65 feet; thence South 659.17 feet; thence South 25°35' East 195.00 feet to a 5/8-inch iron rod; thence South 56° West 110.0 feet to a 5/8-inch iron rod; thence South 34° East 120.79 feet to a 5/8-inch iron rod; thence South 19°30' East 50.42 feet to a 5/8-inch iron rod; thence South 40°32' East 169.38 feet to a 5/8-inch iron rod; thence South 49°29' West 100.0 feet to a 5/8-inch iron rod; thence South 65°00'50" West 51.89 feet to a 5/8-inch iron rod; thence South 52°21'30" West 125.0 feet to a 1/2-inch iron pipe, being the true point of beginning; thence continuing South 52°21'30" West 124.91 feet to a 1/2-inch iron pipe; thence North 21°30'1.2" West 94.480575' to a half inch iron pipe on the arc of a circle with a radius of 50.0 feet, the center point of which bears North 22°01'30" West 50.0 feet from said last-mentioned iron pipe; thence North-easterly along the arc of said circle, through an angle of 69°53'29",

60.99 feet to a 1/2-inch iron pipe; thence North 88°05'01" East 51.00 feet to a 1/2-inch iron pipe; thence South 39°55'35" East 80.0 feet to the true point of beginning. ALSO known as Lot 6, Block 3, CHATEAU RIVIERE, in Clackamas County, Oregon.

Utilities on a Site Plan

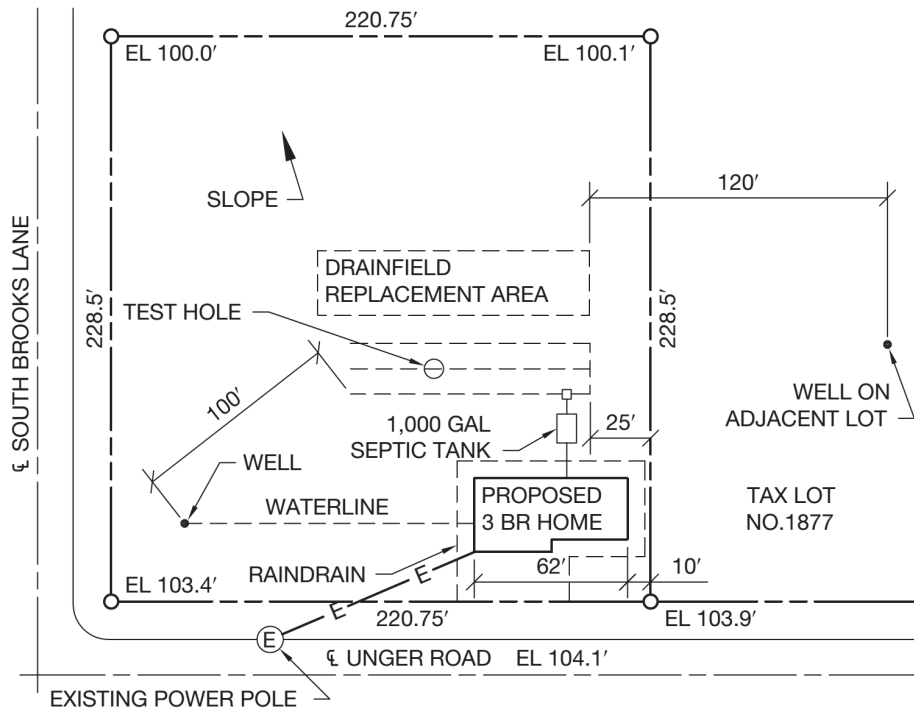
The common utilities displayed on a site plan are electric power, natural gas, telephone, cable TV, potable water, and sewer. **Potable water** is water that is safe to drink. In some cases, a site plan may also show other utility lines including lighting or other specific electrical power; other hazardous material such as oil, steam, and petroleum; other communication lines such as alarm and signal; and other water lines such as irrigation, slurry, or non-potable. **Slurry pipelines** are used to transport mined ore suspended in water to a processing facility as an alternative to other shipping methods such as railway or trucking.

Utilities often originate from main lines existing in a street or utility easement. An **easement** is a legal right-of-way given by a property owner to allow others access to or over the property. An easement can be for access to and from another property, for utilities, or for other uses. When used for utilities, an easement is called a **utility easement** or **public utility easement (PUE)** which is generally a portion of land, shared by a property owner and a public agency, that contains a public utility, such as electrical power, telephone, and/or sewer lines. Detailed specifications about the easement are included in the property legal description. Some utilities, such as electrical power, may be overhead. However, all utilities could be brought to the property from underground. Before you complete a site plan, determine utility locations and where the utilities will enter the property so they can be identified on the proposed plan.

Utilities can be drawn a variety of ways, such as by using hidden lines, thin lines, or thick lines. The lines can be labeled with notes designating their use, or lines can be broken along their length with an abbreviation designating the utility type inserted in the space provided by the break. Generally, solid lines are used to represent aboveground or overhead utility lines, while dashed lines are used to represent underground or underfloor lines. Confirm specific drawing requirements according to applicable drafting standards. Figure 9–15 shows a site plan with electric power from a power pole, potable water from a private well, and sewer in the form of a septic system.

Sewage Disposal Methods

Sewage from residential, commercial, and institutional buildings must be disposed of properly according to state Department of Environmental Quality (DEQ) regulations and local building codes. A site plan is usually required to show the appropriate method of sewage disposal. The following information introduces common, nonindustrial methods of domestic sewage disposal, and how each method appears on a site plan. **Domestic sewage** is the wastewater from toilets, bathtubs,



PLOT PLAN

SCALE: 1" = 50'

SECTION 17, T.6.S, R.8.E WM
CLACKAMAS COUNTY, OREGON
TAX LOT NO. 1876



Figure 9-15. A typical residential building site plan.

showers, laundry, and kitchen. **Storm sewage** is wastewater from rain and groundwater runoff. Storm sewage is processed in a separate storm sewer or, in some cases, with domestic sewage. The local sewage district is usually responsible for providing sewage disposal system drawings and specifications. Chapter 13 shows examples of sewage detail drawings.

Sanitary Sewer

A **sanitary sewer** is a system of underground pipes that transports domestic sewage to a treatment plant where the wastewater is cleaned and discharged. In locations where sanitary, or public, sewers are available, the site plan shows a sewer line from the building to the public sewer line, usually located in the street or in an easement provided somewhere near the property. Figure 9-16a shows a cross section through a public sewer connection. Figure 9-16b shows how a conventional sewer hookup is drawn on a site plan. The sewer line can be drawn using a hidden line and labeled SEWER LINE as shown, or the representation can be a line broken along its length with the abbreviation "S" for sewer, or "SAN" or "SS" for sanitary sewer inserted in the space provided by the break.

Figure 9-16b also shows the centerline of the street, the street name, and the main sewer line. The small circles placed periodically along the main sewer and labeled with the abbreviation MH indicate manholes. A **manhole** is an underground structure used for maintenance access or for making connections to underground utilities and other services, including sewers, telephone, electricity, storm drains, and gas. The manhole is protected by a **manhole cover**, which is a metal or concrete cover designed to prevent accidental or unauthorized access to the manhole. The manhole cover is the round steel or cast iron plate that you typically see in streets and roads. A manhole is sometimes referred to as a **maintenance hole**.

Storm Sewer

A **storm sewer** is a system of underground pipes that carry water runoff from building and land surfaces. Storm sewers are generally shown in or at the edge of the street adjacent to the property, and

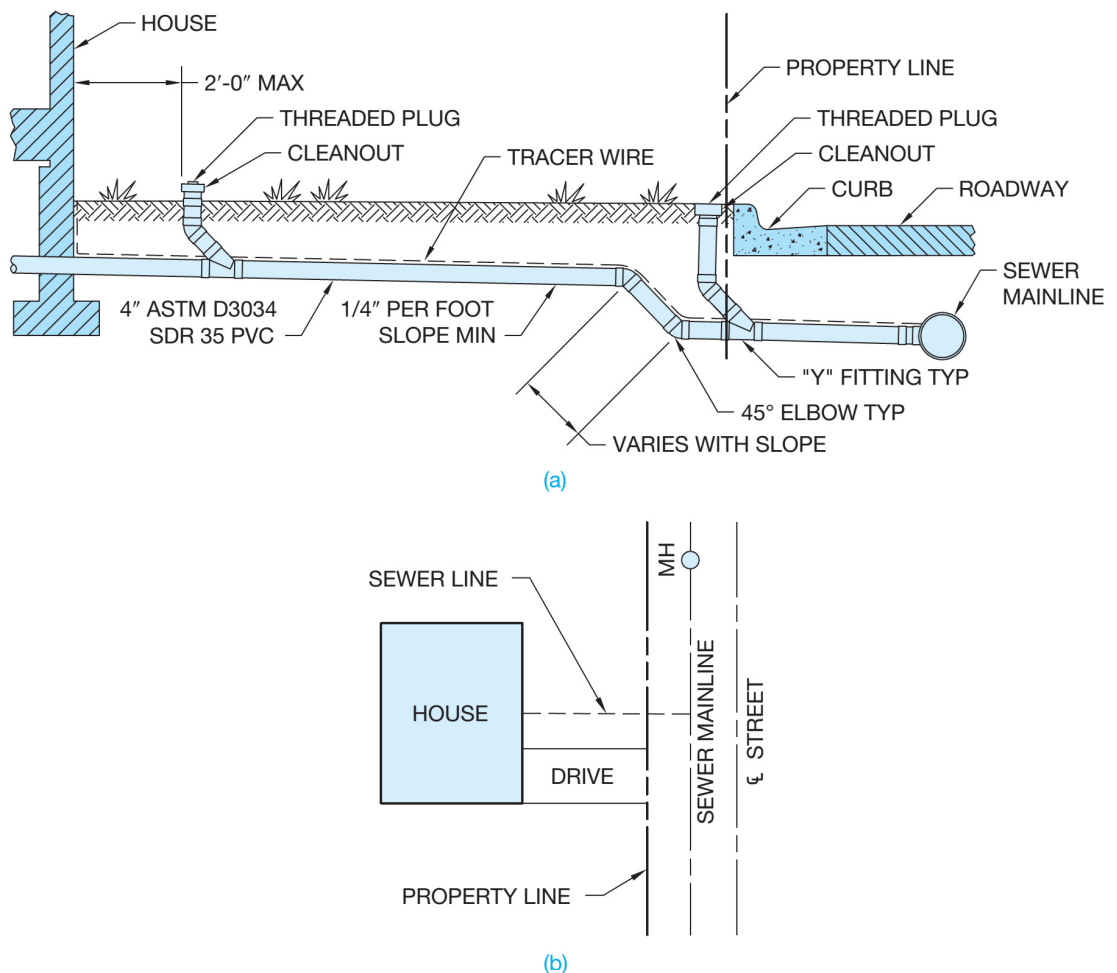


Figure 9-16. (a) A cross section through a typical public sewer installation. (b) A site plan showing a house and public sewer layout.

they can have drainage lines connected to the building or site for rain water distribution. Specific requirements depend on local regulations and specific site conditions. The storm sewer can be drawn as a line broken along its length with the word “STORM”, or “SD” for storm drain, inserted in the space provided by the break.

Septic Tank

In rural settings, domestic sewage is often collected in a concrete or steel box, known as a **septic tank**, installed on the property. A septic tank is designed to hold domestic sewage for two or three days, which is long enough for most heavy, suspended material to sink to the bottom of the tank to form a **sludge**. Lighter, floating material float to the top of the tank, where they remain trapped between the inlet and outlet pipes. After a couple of days, the wastewater portion leaves the tank as **effluent**. Effluent is discharged to the underground piping network, called a soil absorption field.

A **soil absorption field**, also known as a **drainfield** or **leach lines**, is an underground piping network that distributes the effluent over a large soil area, allowing it to percolate through the soil. The drainfield is buried in trenches below the surface of the ground. The soil acts as a filter and disinfectant by removing most of the pollutants and disease-causing viruses and bacteria found in the effluent. Figure 9–17a shows a cross section through a septic tank and a partial absorption field. Figure 9–17b shows how the septic system is drawn on a site plan. The specific dimensions of drainfields and minimum specifications are determined by local requirements. Drainfield lines run parallel to contour lines in order for each drain line to be level.

Cesspool

Cesspools have the same purpose as septic systems, which is to break down and distribute waste materials to an area of the Earth. The soil then acts as a filter to disperse pollutants. Cesspools are used in locations where soil material is very porous, such as an area of gravel or similar material of considerable depth. The cesspool structure is often a large cylinder made of precast concrete, concrete block, or other materials. The cesspool has slots at the bottom for the effluent to escape into a layer of gravel around the tank and then into the porous soil. The local soils department can advise to the type of system that should be used. Figure 9–18a shows the cross section through a typical cesspool. Figure 9–18b shows how a cesspool is drawn on a site plan.

Site Design Considerations

When you design a site plan for a proposed home, addition, or commercial building, many issues need to be considered to make sure the design blends well within the existing environment, allows for good access, protects adjacent properties, and maintains the integrity of the surrounding area. Several issues that can affect the quality of the

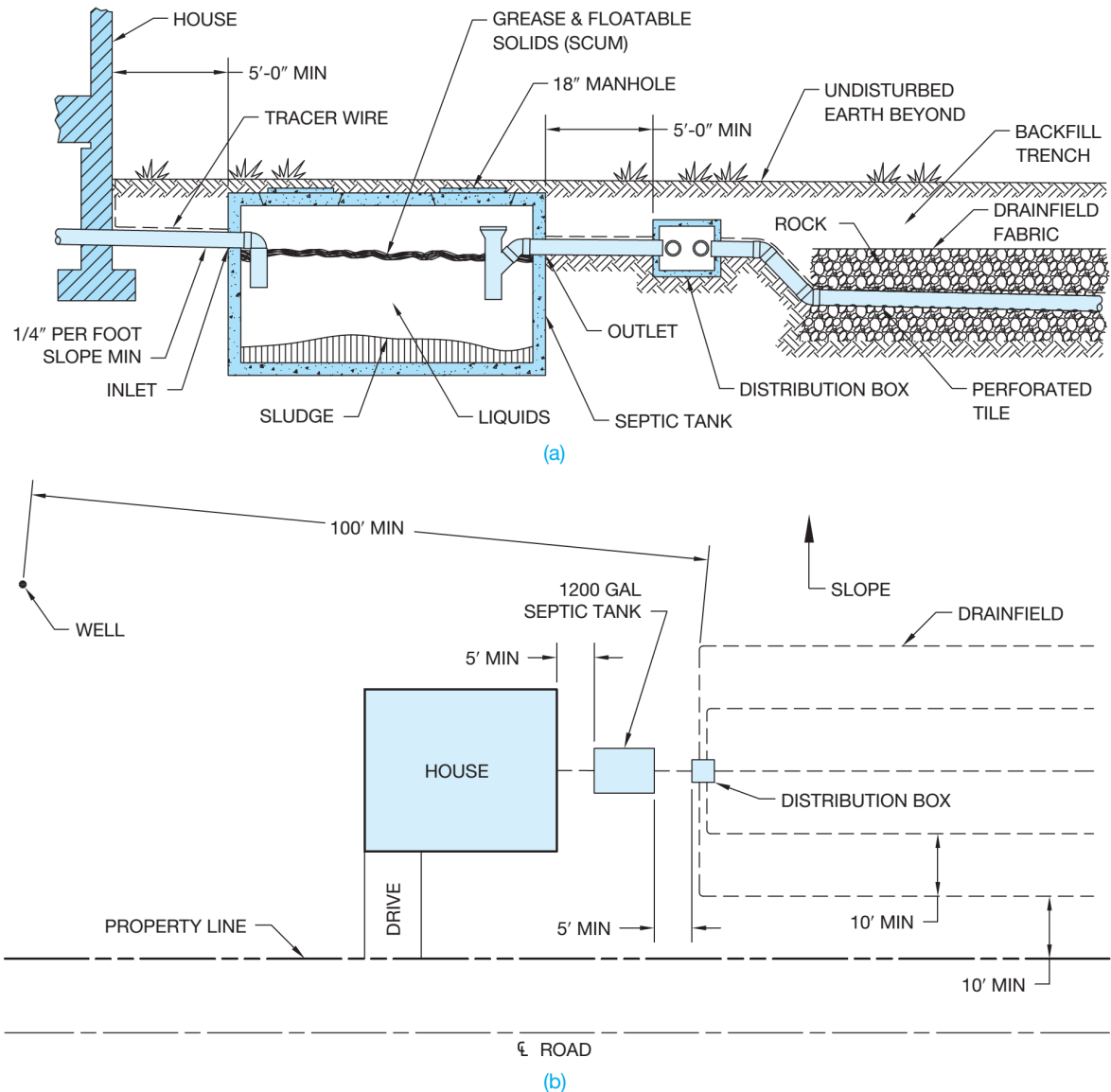


Figure 9-17. (a) A cross section through a typical septic tank. (b) A site plan showing a house and septic system.

construction project and adjacent properties should be considered during site design. Some of these factors are outlined in the following information and are presented as suggested recommendations to consider. The use of any one or more site design elements depends on the specific site:

- Provide a minimum driveway slope of 1/4" per ft. The maximum slope depends on surface conditions and local requirements.
- Provide a minimum lawn slope of 1/4" per ft. if possible.
- Single-car driveways should be a minimum of 10' (3 m) wide, and double-car driveways should be a minimum of 18' (5.5 m) wide but can taper to a minimum of 10' (3 m) wide at the entrance if

necessary. Any reduction of driveway width should be centered on the garage door. A turning apron is preferred, when space permits. This allows the driver to back into the parking apron and then drive forward into the street, which is safer than backing into the street.

- The minimum turning radius for a driveway should be 15' (4.5 m). The turning radius for small cars can be less, but more should be considered for trucks. A turning radius of 20' (6 m) is preferred if space permits. Figure 9–19 shows a variety of driveway layouts. The dimensions are given as commonly recommended minimums for small- to standard-sized cars. Additional room should be provided, if available.
- Provide adequate room for the installation of and future access to electric, gas, telephone, cable TV, water, and sewer utilities.
- Do not build over established easements.
- Follow basic grading rules, which include not grading on adjacent property. Do not slope the site so as to cause water drainage onto adjacent property. Slope the site away from the structure. Adequate drainage of at least 10' (3 m) away from the building is recommended.
- Identify all trees that are to remain on the site after construction.
- Establish retaining walls where needed to minimize the slope, control erosion, and level portions of the site.

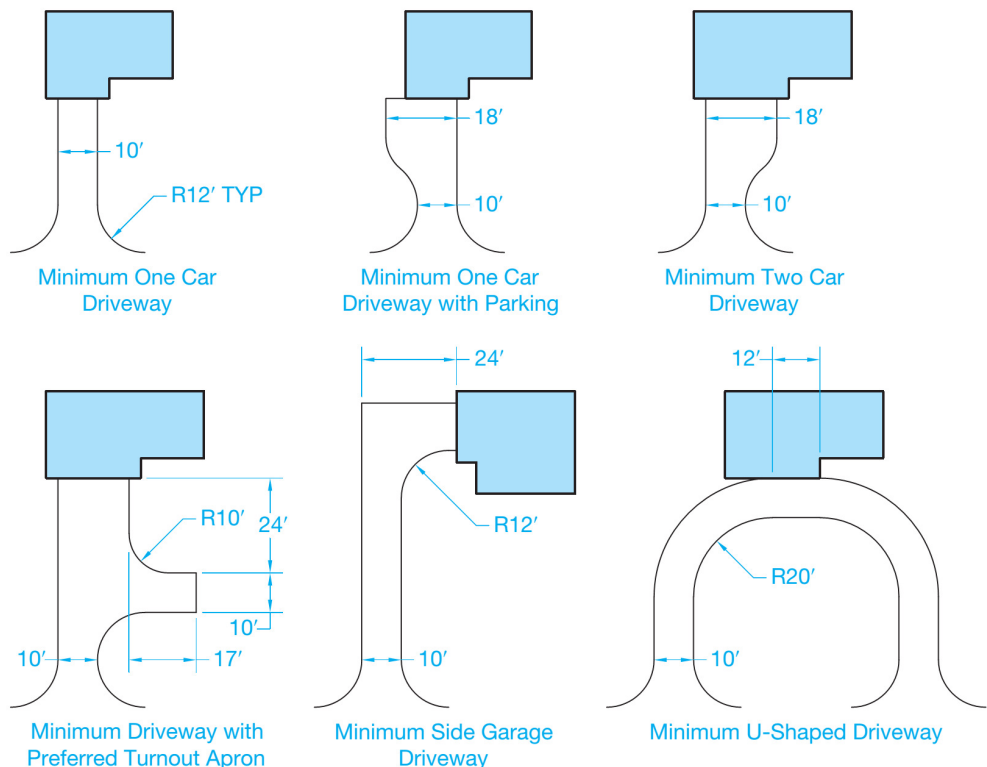


Figure 9–19. A variety of driveway layouts. The dimensions are given as commonly recommended minimums for small- to standard-sized cars. Additional room should be provided, if available.

Rural Residential Fire Department Access and Site Planning

Special considerations need to be made when designing driveways and turnarounds in rural areas. In urban and suburban areas, fire truck access is normally designed into the subdivision plan, and each residence should be fairly easy to access for firefighting purposes. Rural locations can present special problems for firefighting because they are often larger pieces of property that frequently have long gravel driveways where access can be limited. The guidelines governing site design can differ from one location to the next, but the following are common standards for your consideration:

- For road clearances, a 15' (4.5 m) minimum width all-weather surface driveway must be provided with an additional 5' (1.5 m) width clear of vegetation. **All-weather** means gravel or paved surface. The driveway should also be clear of vegetation to a height of 13'-6" (4 m). Figure 9-20 shows several basic driveway design options.
- The driveway should be engineered for a 12,500-lb. wheel load and 50,000-lb. gross vehicle load.
- A 10% average maximum road grade is preferred, but up to 15% for 200' (60 m) is acceptable.
- Provide a turnaround, at the end, if the driveway is longer than 150' (45 m).
- Provide a 20' (6 m) wide by 40' (12 m) long passage space at the midpoint of every 400' length.
- Bridges and culverts should be designed to support a minimum of 50,000 lb.

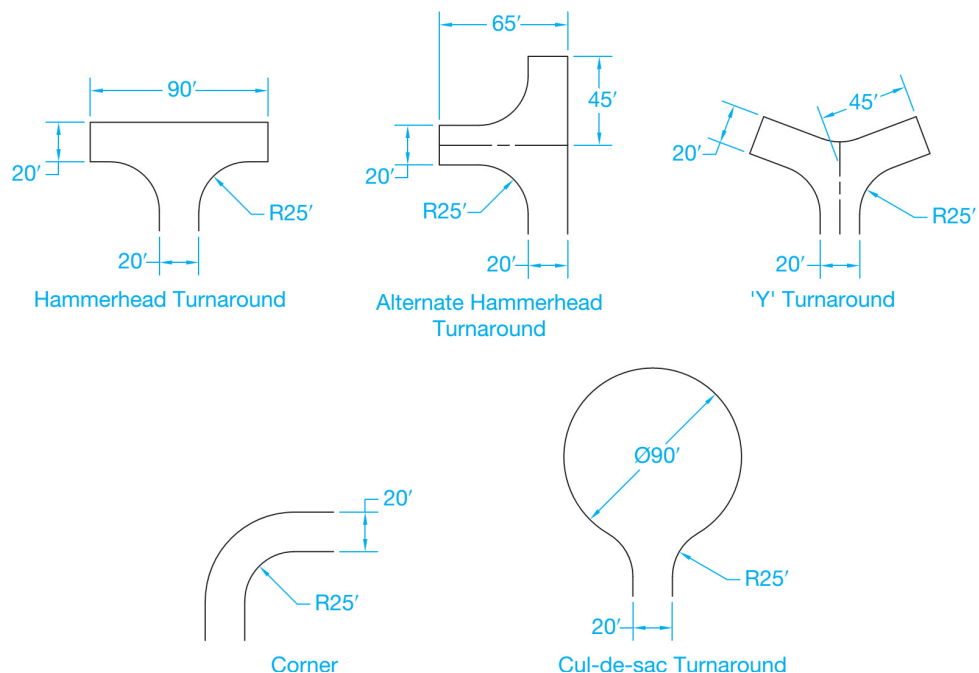


Figure 9-20. Several basic driveway design options for rural residential fire department access.

- Provide a firebreak of at least 30' (9 m) around all structures. A **firebreak** requires ground cover no more than 24" in height, with all dead vegetation removed. Steep terrain around the structure can require a greater firebreak.
- The property address should be posted on a fire department approved sign where the driveway meets the main road.
- On-site water supplies, such as a swimming pool, pond, or water storage tank, should be accessible within 15' (4.5 m) for fire suppression. A fire sprinkler system designed and installed in the home can be substituted for a water supply.
- The use of wood roofing material or other combustible materials is restricted in wildfire zones. **Wildfire zones** are heavily wooded areas and can be confirmed at the local building official or zoning office.

Site Plan Layout

Survey data, building codes, and project design characteristics provide the information needed to lay out a site plan. The following information offers a valuable introduction to laying out a site plan using manual CADD tools with software such as AutoCAD. The recommended steps used to create a site plan allow you to design the plot and then add structures, utilities, and annotations. Figure 9–21 shows a small subdivision plat and the individual lots, or plots, found in the plat. The following example focuses on creating a site plan for Lot 3. If a plat is not available, then the plot plan can be laid out from the legal description by establishing the boundaries using the given bearings and dimensions. The Lot 3 site plan will be drawn on an 18" × 24" (architectural C) size sheet at a 1" = 10' scale.

Drawing Property Lines

The initial step to laying out a site plan is to draw the property lines. Generally, the plat or legal description provides metes and bounds coordinates for property line boundaries. The property lines of a lot and the boundaries of a plat are commonly labeled with distances and bearings. For example, the northwest property line of Lot 3 is 43.21' in length at a S60°03'44"W bearing angle. Figure 9–22a shows how the west property line is drawn and labeled. When using AutoCAD, for example, set architectural or engineering length units to specify distance in feet, and surveyor's angular units to specify bearing angles. From the point at the northwest corner of Lot 2, input: @43.21'<S60d03'44"W to draw the northwest property line. Notice that the degree symbol (°) is replaced with the lowercase letter d when entering a bearing.

Many plats have property lines that are arc-shaped, such as the lines around the cul-de-sac shown in Figure 9–21. The dimensions of each arc, or curve, can be specified using specific notes and/or in a curve table. The curves in Figure 9–21, for example, are each given a name keyed to a curve table. Examples of curve data on a drawing are the centerline length (L), radius (R), chord length, bearing of the chord,

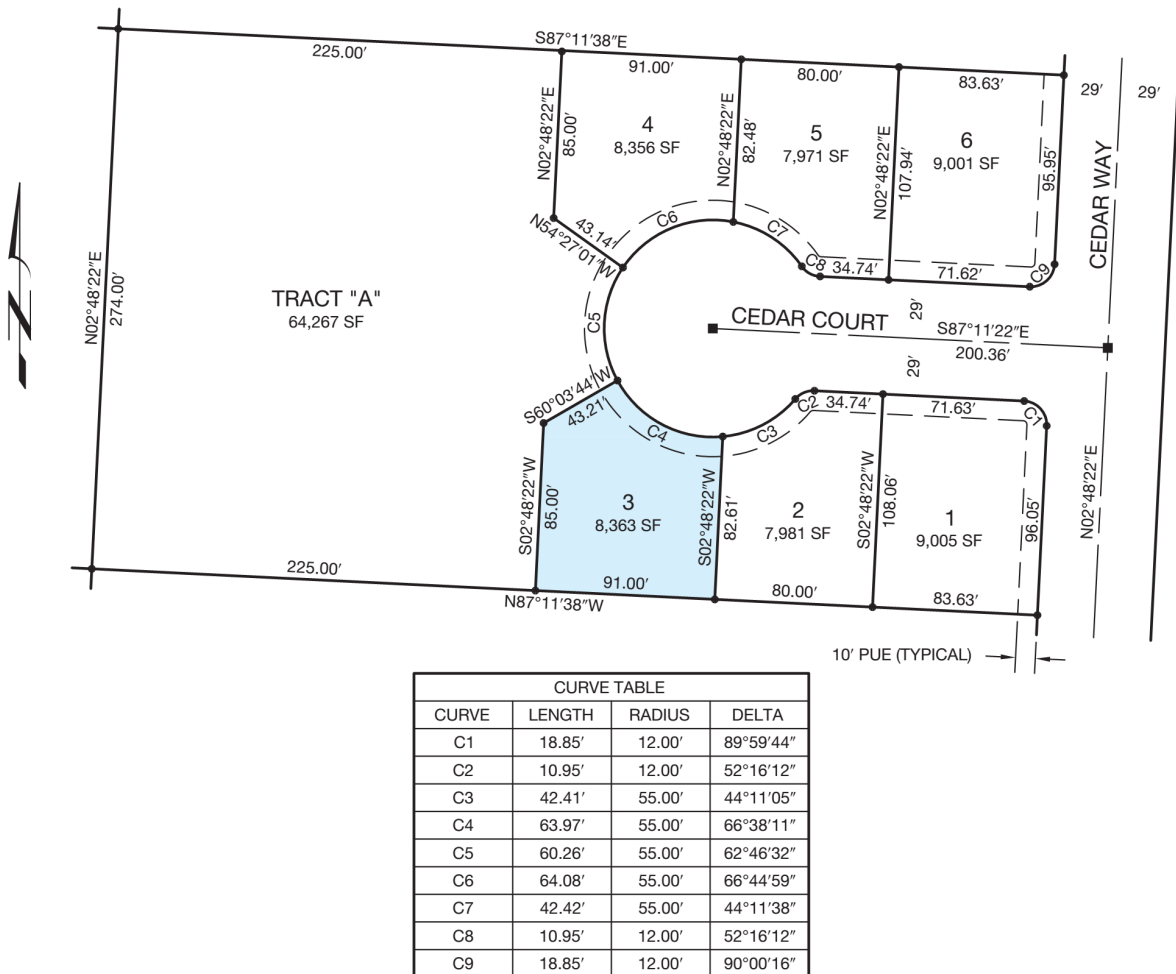


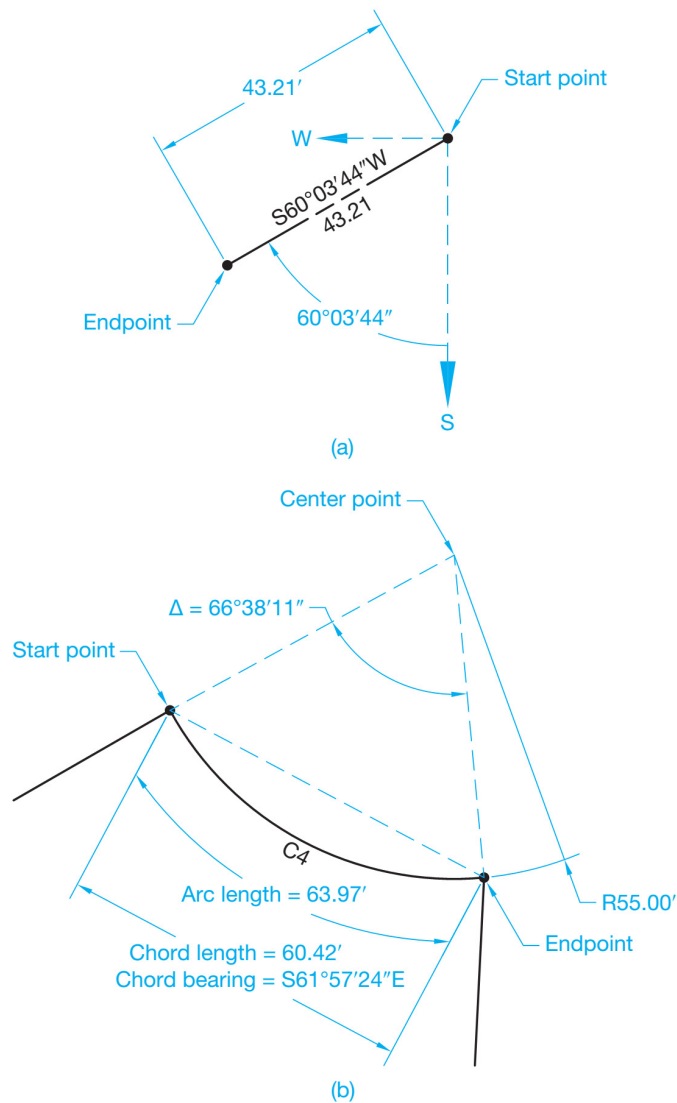
Figure 9-21. A small subdivision plat and the individual lots, or plots, in the plat.

and delta angle (Δ). A **chord** is a linear distance between two points on a circle or arc. A **delta angle** is the included angle of a curve. An **included angle** is the angle formed between the vertex and the two sides. You will learn more about curves in Chapter 10. Figure 9-22b shows how the north, curved property line is drawn and labeled. CADD ARC command options typically allow you to draw arcs according to a variety of curve data. Select the appropriate option based on the information you know about locating and constructing the arc.

Adding Structures and Utilities

Once you draw the property lines, you are ready to begin placing structures, utilities, and other site plan features. The required items and locations of features are based on the site design considerations, architectural design and site layout, existing and proposed utilities, and local regulations. All structures must be inside or on the minimum setback requirements, and away from easements. **Setbacks** are imaginary boundaries beyond which the structure cannot be placed. Think

Figure 9-22. (a) Drawing and labeling a straight property line. (b) Drawing and labeling an arced property line.



of setbacks as property line offsets established by building codes. Confirm minimum setbacks with local zoning regulations. The minimum setbacks for the Lot 3 example are 20' front to a garage, 5' sides, and 15' back from property lines to the house (see Figure 9-23).

The proposed house in the Lot 3 project is 51'-6" deep by 48' wide. The house can be drawn on the site plan with or without showing the roof depending on whether or not the roof overhang is considered in the setback according to local codes. If the setback is to the walls of the structure, as with the Lot 3 example, a common practice is to draw only the outline of the floor plan or foundation. If the setback is to the roof overhang, the house outline can be drawn as hidden, or dashed, lines under the roof. Figure 9-24 shows the proposed house, driveway, walkway, driveway apron, and sidewalk. Some drafters use a thick line or a graphic pattern for structures, and graphic patterns for hard surfaces such as concrete driveways and walkways. Figure 9-25 shows utilities added to the site plan.

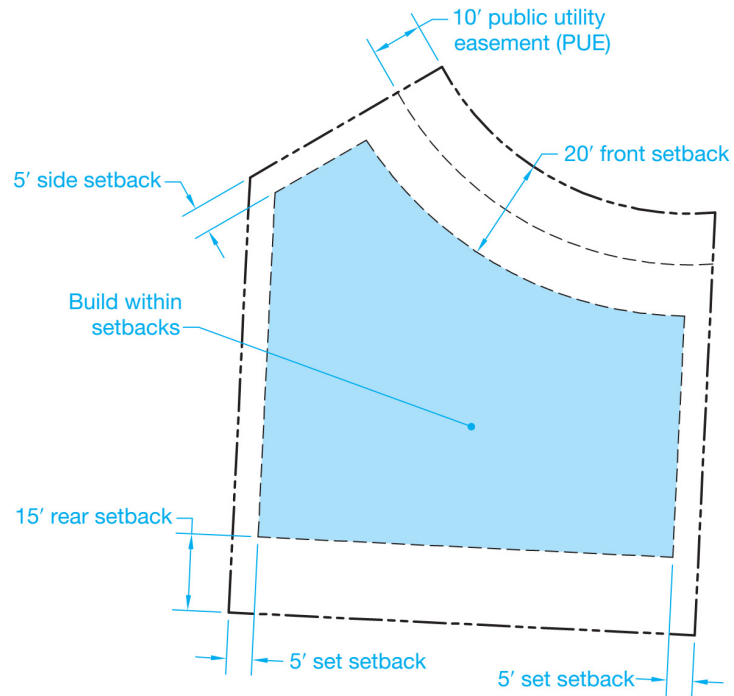


Figure 9-23. Once you lay out the property lines, draw setbacks and easements.

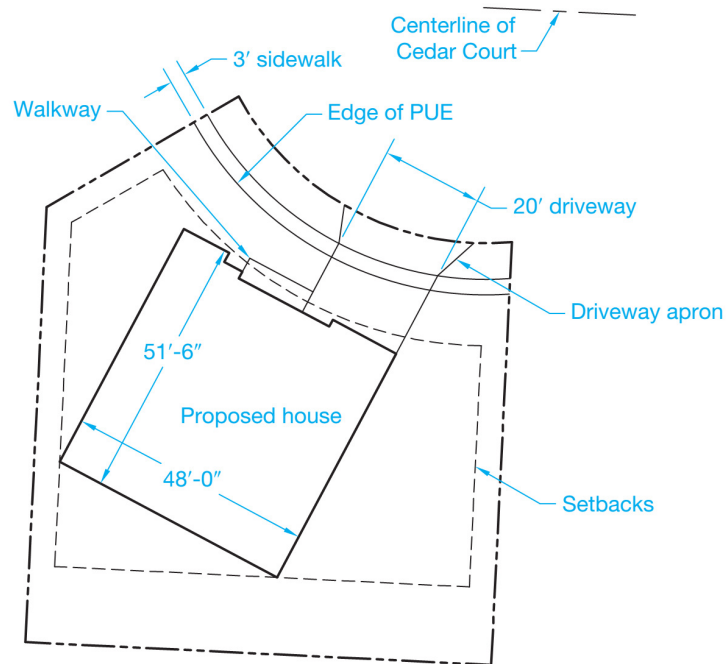


Figure 9-24. Laying out the structures, roads, driveways, and walks. Be sure the structure is on or within the required minimum setbacks. Use proper CADD layers when drawing the different features of a site plan.

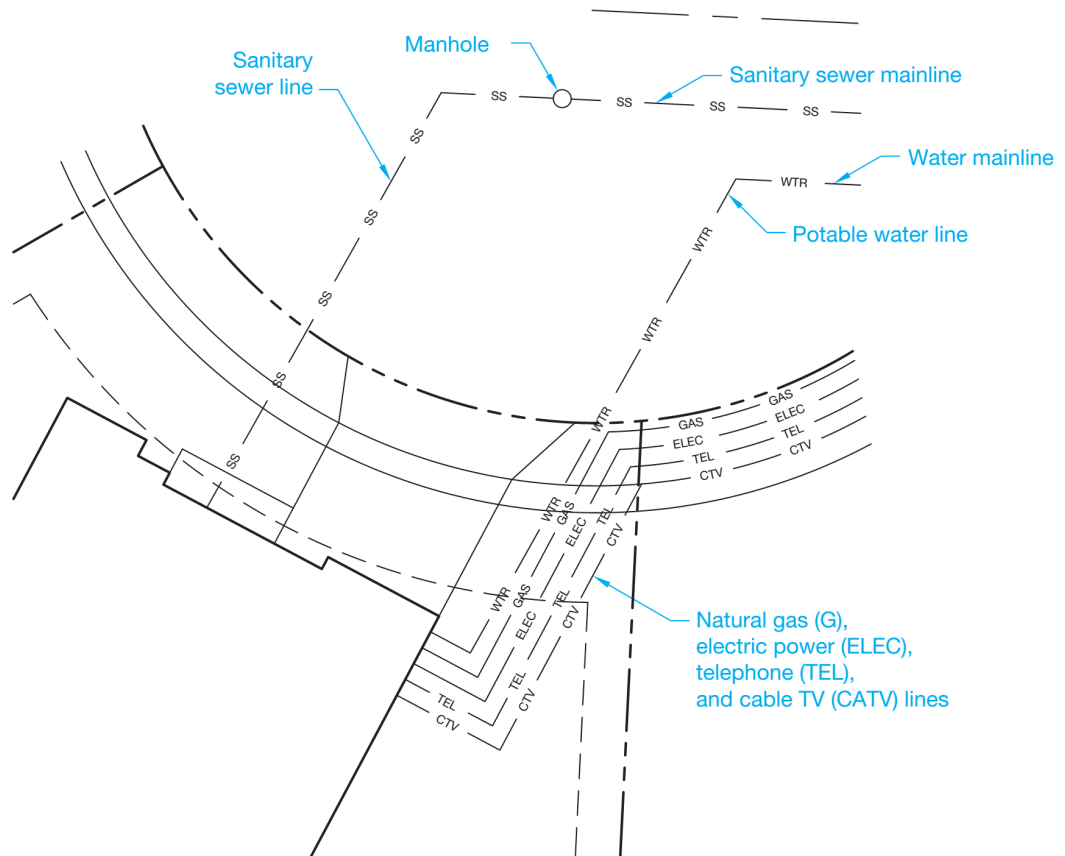


Figure 9-25. Laying out the utilities.

Completing the Site Plan

Add dimensions, notes, other annotations, and symbols as required to complete the site plan. Figure 9-26 shows the completed site plan drawn on an 18" × 24" (architectural C) size sheet at a 1" = 10' scale. The drawing includes all necessary dimensions, and corner and floor level elevations. Contour lines are not required for this example. The property line dimensions are generally placed on the inside of the property lines in decimal feet, and the bearing is placed on the outside of the property lines.

The dimensions locating and giving the size of the structure are commonly provided in feet and inches or in decimal feet. Locate all proposed and existing structures with dimensions from property lines and dimensions provided between structures. Try to keep extension and dimension lines to a minimum on the site plan. One way to do this is to dimension directly to the building outline and place size dimensions inside the structure outline. Add all notes, including road names, utility names, walks, and driveways. Finally, add a north arrow, graphic scale, legal description and other necessary site notes, address of the property, title, scale, owner's name and contact information, and other title block information.

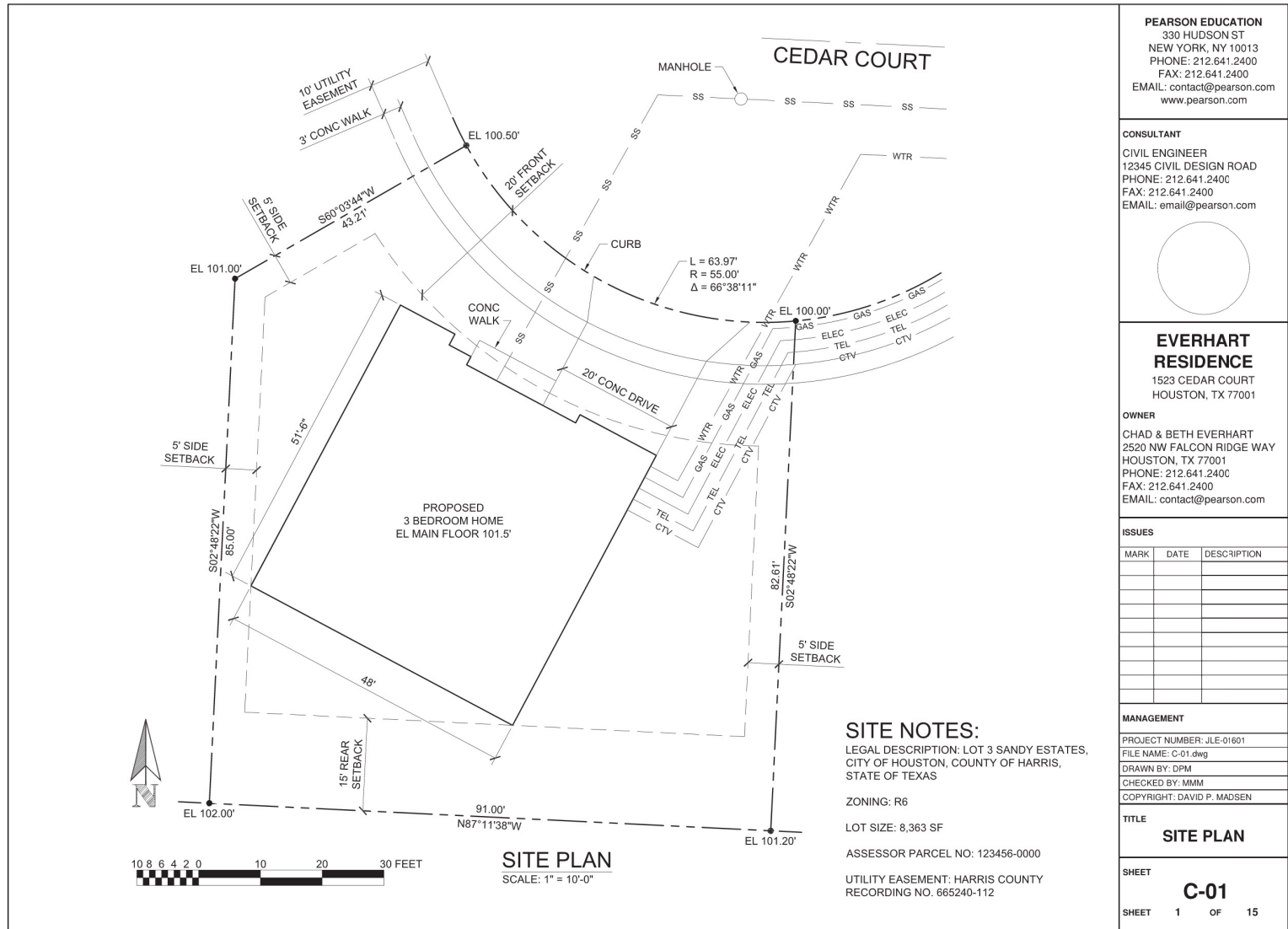


Figure 9-26. Complete the site plan by adding dimensions, elevations, notes, a north arrow, graphic scale, legal description and other necessary site notes, address of the property, title, scale, owner's name and contact information, and other title block information.

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Define the following terms.

9-1 Site plan

9-2 Plat

9-3 Vicinity map

9-4 Project map

9-5 Subdivision

Part 2

Identify whether the statement is true or false. Reword all false statements so that the meaning is true.

9-6 A plot plan becomes a legal document containing an accurate drawing and a legal description of the land.

9-7 Site analysis is a system of land use planning and public restrictions applied by local governments.

9-8 Grading plans are construction drawings that generally show existing and proposed topography.

9-9 A planned unit development (PUD) only allows zoning for single- and multifamily homes.

9-10 A PUD plan often includes a land use summary and displays special spaces, such as recreational and open spaces, or other unique characteristics.

Part 3

Given the PLSS section shown in Figure R9–1 with areas labeled by letters, provide the legal description and the number of acres for each area.

9–11 A

9–12 B

9–13 C

9–14 D

9–15 E

9–16 F

9–17 G

9–18 H

9–19 I

9–20 J

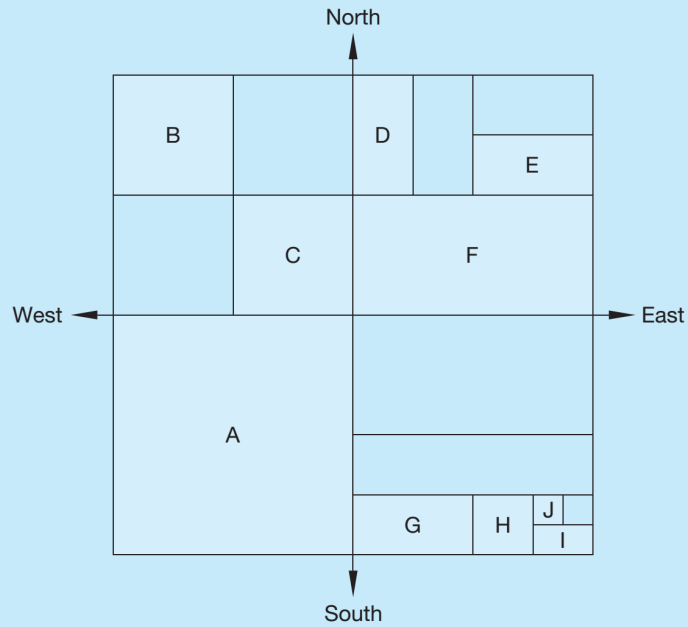


Figure R9-1.

Part 4

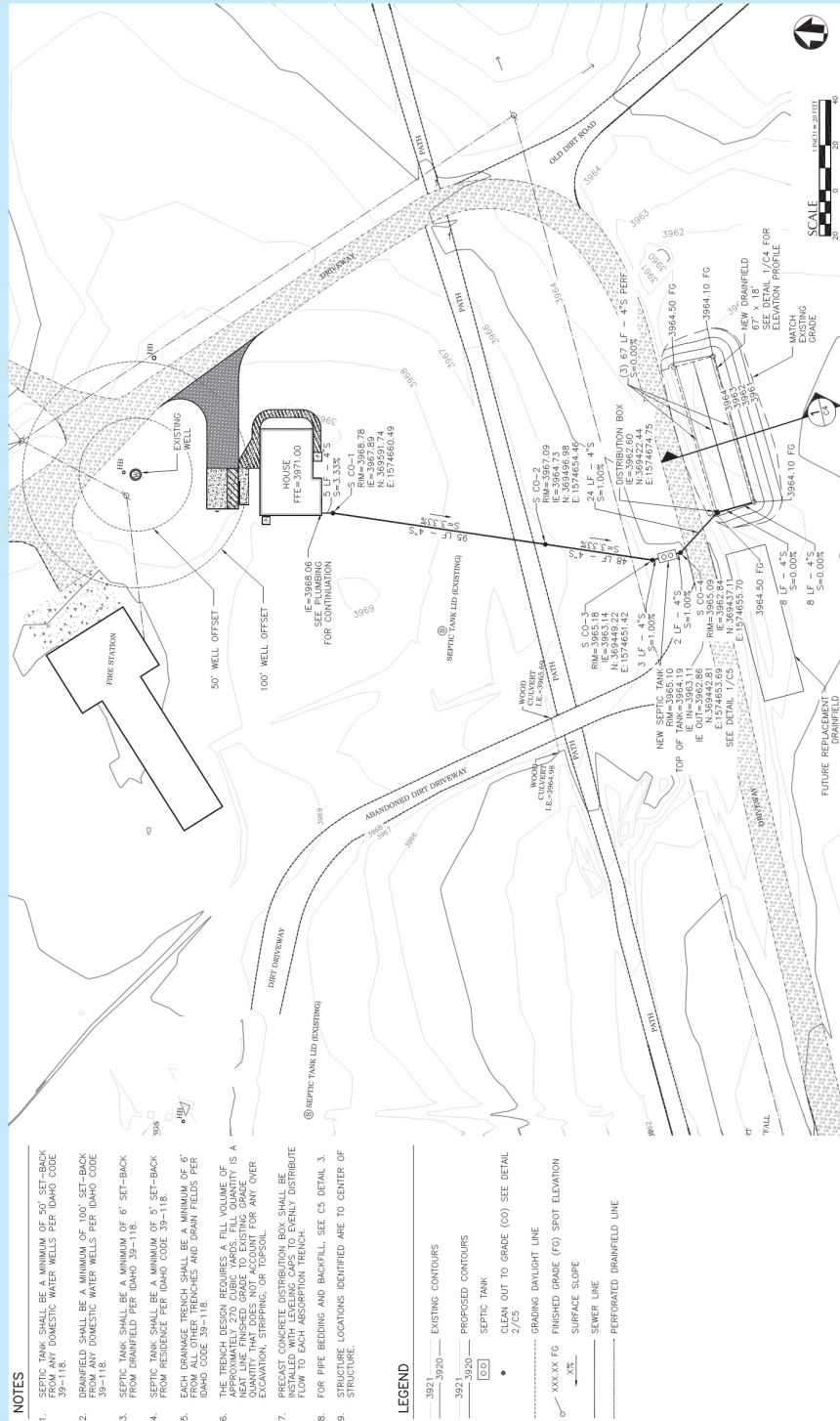
Sketch an example of the following plot plan characteristics.

- 9-21** Public sewer to house on plot. Show driveway to house from street.
- 9-22** Septic system to house on plot. Show driveway to house from street.
- 9-23** Cesspool to house on plot. Show driveway to house from street.
- 9-24** Hammerhead turnaround.

Part 5

Study the portion of the site plan shown in Figure R9–2 to answer the following questions. The entire plan is available for download and viewing. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Chapter 9 Plan.pdf.

- 9–25** The drawing scale is _____, and north is toward the _____ of the sheet.
- 9–26** The total number of existing wells on the site is _____, and the total number of existing septic tanks is _____.
- 9–27** The existing culverts identified on the plan are made of _____, and cross under the _____.
- 9–28** The elevation of the highest index contour line is _____, and the elevation of the lowest index contour line is _____. The elevation of the finished floor (FFE) of the house is _____.
- 9–29** The minimum distance from the septic tank to any domestic water well is _____, and the minimum distance from the drainfield to any domestic water well is _____.
- 9–30** The length and width of the new drainfield is _____ × _____, and the finished grade (FG) elevation of the northeast corner of the drainfield is _____.
- 9–31** The minimum distance from the septic tank to drainfield is specified in Note _____, and the minimum distance from the septic tank to a residence is specified in Note _____.
- 9–32** The total number of cleanouts along the sewer line for the septic system is _____.



PROBLEMS

Follow the specific instructions to complete each problem.

Part 1

Complete the following written assignment and presentation.

- P9-1** Research and write a report of approximately 250 words describing the process and requirements to submit a residential site plan for approval to the city or county in which you live. Include a checklist of items that the site plan should display. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.

Part 2

Use the following information to draw the specified plats:

- Use an ANSI B size sheet.
- Choose an appropriate scale, such as $1'' = 20'$ or $1'' = 50'$, to make the plat as large as possible within the $1/2''$ minimum margin to the edge of the drawing field.
- Use a basic border and title block, and complete all necessary title block fields.

- P9-2** See Figure P9-2.



Figure P9-2.

P9-3 See Figure P9-3.

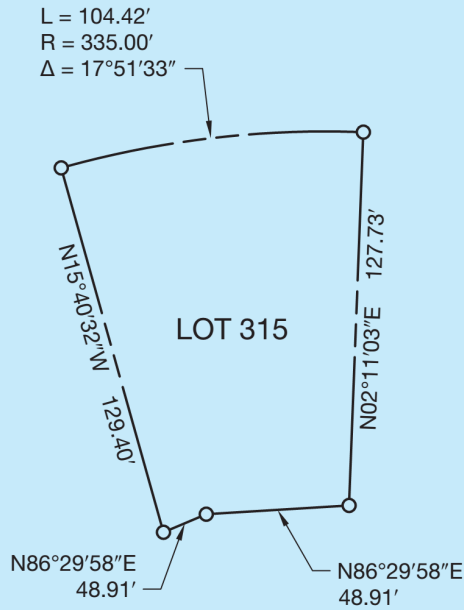


Figure P9-3.

P9-4 See Figure P9-4.

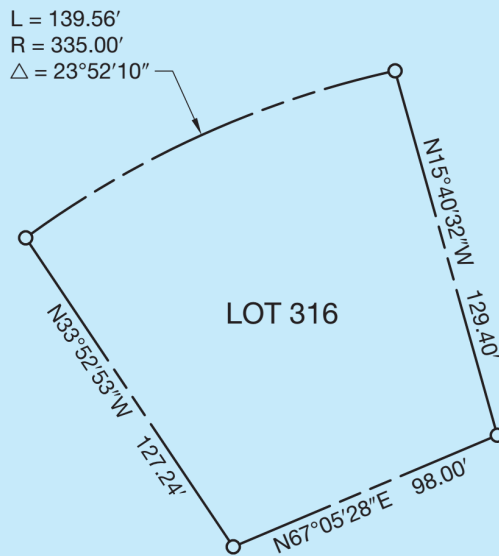


Figure P9-4.

P9-5 See Figure P9-5.

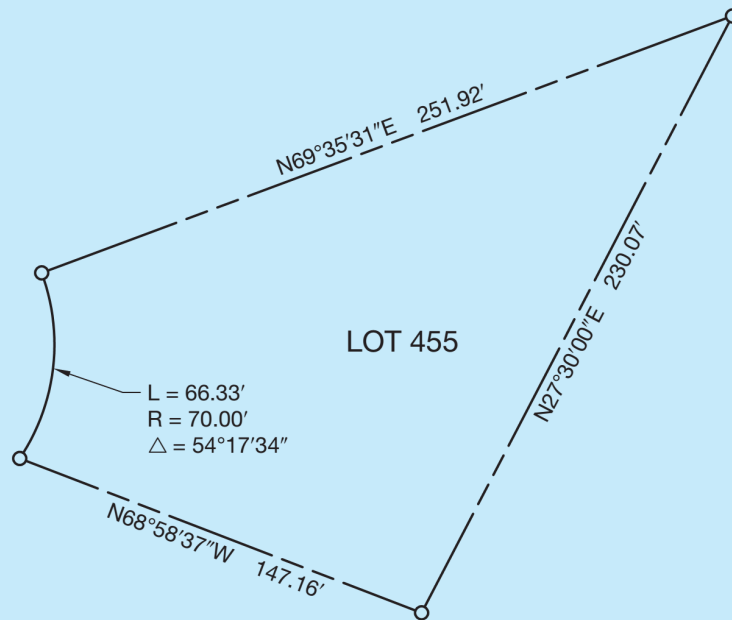


Figure P9-5.

P9-6 See Figure P9-6.

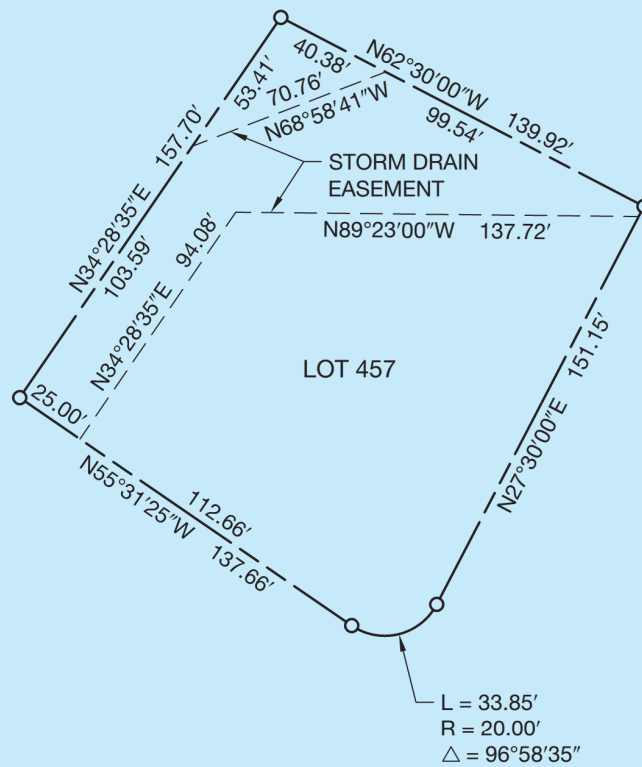


Figure P9-6.

Part 3

Use the following information and the specified sketches to create drawings. The sketches are not to scale.

- Choose an appropriate sheet size, such as ANSI B, ANSI C, or architectural C size sheet.
- Choose an appropriate scale, such as $1'' = 10'$, $1'' = 20'$, $1'' = 50'$, or $1'' = 60'$, to make the site plan as large as possible within the $1/2''$ minimum margin to the edge of the drawing field.
- Use as many of the site plan requirements described in this chapter as possible, and include the title, scale, graphic scale, north arrow, legend, total acres or square feet, elevations given, dimensions, notes, and legal description.
- Use a suitable border and title block, and complete all necessary title block fields.

P9-7 See Figure P9-7.

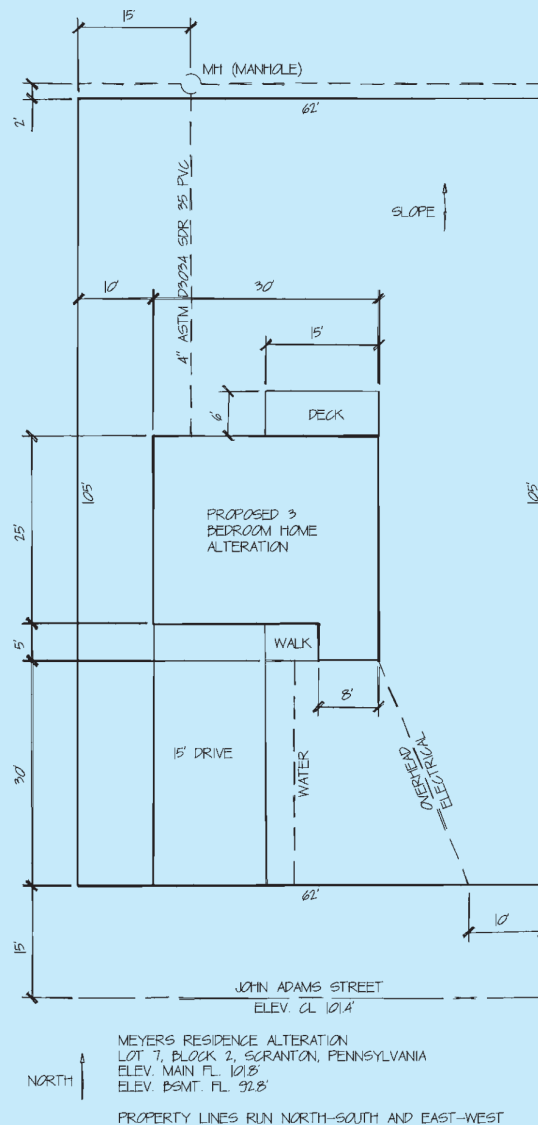


Figure P9-7.

P9-8 See Figure P9-8.

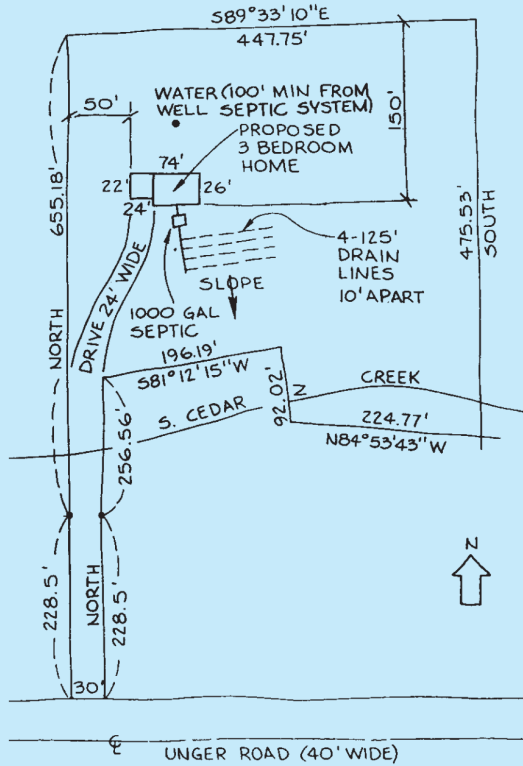


Figure P9–8.

Part 4

Draw property boundaries from the legal or site descriptions provided. Use an appropriate sheet size and drawing scale. Include the title, scale, north arrow, total acres and square feet, and legal description.

P9-9 Legal Description:

All that portion of Lot 140, commencing at the Southwesterly corner and thence continuing along said parallel line, North 0 Degrees 22 Minutes East, 50.00 feet; thence South 89 Degrees 38 Minutes East, 270.85 feet to a point in the centerline of Hillside Drive; thence South 58 Degrees 28 Minutes West, 12.98 feet to an angle point in said centerline; thence continuing along said centerline, South 36 Degrees 42 Minutes West, 102.0 feet; thence leaving said centerline, North 78 Degrees 34 Minutes West, 203.46 feet to the TRUE POINT OF BEGINNING.

P9-8 See Figure P9-10.

SITE DESCRIPTION Starting at a point on the west side of the 35' right of way of El Corto Street, San Marcos, California:		
Station	Bearing	Distance
1 POB	S75°00'E	310.01'
2	N23°00'E	276.06'
3	N27°30'W	221.63'
4	S23°30'W	420.07'
5	N75°00'W	143.32'
6	S02°45'W	22.23'
LEGAL DESCRIPTION A portion of Lot #9, in block "L" of Charles Victor Hall Tract Unit #2, Map No. 2056 filed in the office of the County Recorder of San Diego County, State of California, on September 22, 2016.		

Figure P9-10.

P9-11 Legal Description:

That portion of Lot 6, commencing at the most Northerly corner of that parcel of land delineated and designated as "1.17 Acres (Net)"; thence South 55 Degrees 17 Minutes 37 Seconds East, 203.85 feet to the Northwestern boundary of County Road (Highland Drive) being a point on the arc of a 165.88 foot radius curve concave Northwesternly, a radial line of said curve bears South 13 Degrees 38 Minutes 13 Seconds East to said point; thence along said Northwesternly boundary as follows: Westerly along the arc of said curve through a central angle of 10 Degrees 17 Minutes 13 Seconds a distance of 29.78 feet to the beginning of a reverse 170.0 foot radius curve; Southwesterly along the arc of said curve through a central angle of 52 Degrees 40 Minutes a distance of 156.27 feet to the point of tangency in the Southeasterly line of said Lot 6; and along said Southeasterly line tangent to said curve South 33 Degrees 59 Minutes West, 37.91 feet to the most Southerly corner of said land; thence North 56 Degrees 01 Minute West, 115.00 feet to a line which bears South 33 Degrees 59 Minutes West from the True Point of Beginning; thence North 33 Degrees 59 Minutes East, 195.73 feet to the TRUE POINT OF BEGINNING.

P9-12 Legal Description:

Starting at a point on the North side of the 66 feet right of way of Edgewood Drive; thence N61°56'33"E for a length of 184.24 feet; thence N1°16'55"W for a length of 715.37 feet; thence S89°44'40"W for a length of 164.51 feet; thence S1°16'55"E for a length of 801.32 feet to the point of beginning.

P9-13 Legal Description:

All that portion of Lot Four (4) in Block One Hundred Forty-nine (149) of the City of Escondido, as per Map thereof No. 336, filed in the Office of the County Recorder of said San Diego County, July 10, 1886, described as follows:

Beginning at a point on the centerline of Grant Avenue, North 69°43' East, a distance 240.0 feet from the centerline intersection of North Broadway and Grant Avenue, which said letter point is the Northwest corner of said Lot Four (4) of Block One Hundred Forty-nine (149); thence North 69°43' East along the centerline of said Grant Avenue, a distance of 317.0 feet to a point; thence South 00°57' East 96.0 feet; thence South 10°40' West 166.0 feet; thence South 69°43' West 200.0 feet; thence North 20°17' West 233.0 feet; more or less, to the point of beginning, and containing 1.42 acres, more or less.

P9-14 See Figure P9-14.

PROPERTY LEGAL DESCRIPTION		
POB is the center of Bear Road, which is 66.0' feet wide:		
Station	Bearing	Distance
1 POB	N03°45'E	560.5'
2	N00°15'W	619.2'
3	N45°00'E	425.3' Top of river bank
4	N45°00'E	80.6' Center of Indian River
5	S78°10'E	232.0'
6	S59°45'E	238.5'
7	S50°45'E	270.7'
8	S23°15'E	318.8'
9	S71°30'E	200.4'
10	S07°45'W	430.5' Top of river bank
11	S07°45'W	114.5' Center of Indian River
12	DUE WEST	451.3'
13	S00°10'W	397.3'
14	N79°00'W	465.1'
15	N88°47'W	365.0' To POB

Figure P9-14.

P9-15 See Figure P9-15

PROPERTY LEGAL DESCRIPTION		
Flemming Property Corner of Birmingham and MacKinnon Cardiff, California File No. SB5501		
Point No	Bearing	Distance
47 POB	N00°52'00"E	95.000'
39	N27°28'50"E	19.875'
42	N25°36'2"E	102.600'
Point No	Curve Data	
165 ARC CENTER	L = 22.556' R = 102.600' Δ = 12°39'01" BEARING = S38°15'03"W	
Point No	Bearing Distance	
112	S38°15'03"W	130.000'
Point No	Curve Data	
162 ARC CENTER	L = 53.174' R = 130.000' Δ = 23°26'09" BEARING = N14°48'54"E	
Point No	Bearing Distance	
116	S63°53'58"W	25.040'
117	S73°22'11"W	23.250'
118	S77°50'06"W	23.510'
119	S68°44'46"W	23.410'
120	S01°24'39"W	52.230'
124	N89°53'24"E	99.000'
129	S02°05'19"W	64.988'
45	N89°56'50"E	50.000' To POB

Figure P9-15.

P9-16 Legal Description:

All that portion of Lot 12 of MARTIN'S ADDITION TO VISTA, in the County of San Diego, State of California, as shown on Map No. 1472, on file in the Office of the County Recorder of said San Diego County, described as follows:

Beginning at a point of intersection of the Southeasterly line of said Lot 12, with a line drawn parallel with and distant 140.00 feet, measured at right angles Northeasterly from the Northeasterly line of Citrus Avenue, 60 feet wide, as shown on said Map No. 1472, said point being the Southeasterly corner of the land conveyed to William Allington by deed dated February 02, 1933, and recorded in Book 188 Page 391 of Official Records of said San Diego County; thence North 30 Degrees 18 Minutes West along the Easterly line of land so conveyed, being also the aforementioned parallel line, 186.45 feet to an angle point in said Easterly line; thence continuing along said Easterly line, being parallel with and distant 140.00 feet at right angles Easterly from the Easterly line of said Citrus Avenue, North 0 Degrees 22 Minutes East 141.97 feet to the TRUE POINT OF BEGINNING; thence continuing along said parallel line, North

0 Degrees 22 Minutes East, 50.00 feet to a point distant thereon South 0 Degrees 22 Minutes West, 100.00 feet from the Southerly line of the Northerly 4.0 Acres of said Lot 12, as said Northerly 4.0 Acres were conveyed to H. B. Morris, et ux, by deed dated April 14, 1930, and recorded in Book 1784 Page 187 of Deeds; thence parallel with and 100.00 feet Southerly at right angles from said Southerly line of said Northerly 4.0 Acres as conveyed to said Morris, South 89 Degrees 38 Minutes East, 270.85 feet to a point in the centerline of Hillside Drive as shown on said Map No. 1472; thence along said centerline of said Hillside Drive, South 58 Degrees 28 Minutes West, 12.98 feet to an angle point in said centerline; thence continuing along said centerline, South 36 Degrees 42 Minutes West, 102.0 feet; thence leaving said centerline, North 78 Degrees 34 Minutes West, 203.46 feet to the TRUE POINT OF BEGINNING.

P9-17 Legal Description:

That portion of Lot 6 in Block 4 of Keeney's Marine View Gardens, in the County of San Diego, State of California, according to Map thereof No. 1774, filed in the office of the County Recorder of San Diego County, December 31, 1923, lying within the following described boundary:

Commencing at the most Northerly corner of that parcel of land delineated and designated as "1.17 Acres (Net)" on Record of Survey Map No. 4270, filed in the Office of the County Recorder of San Diego County, April 18, 1957, being also the most Northerly corner of land described in deed to John R. Minton, et ux, recorded December 23, 1964, as File No. 232,023; thence along the Northeasterly line of said Minton's land, South 55°17'37" East, (Record South 55°52'00" East) 115.01 feet to the TRUE POINT OF BEGINNING; thence continuing along said Northeasterly line South 55°17'37" East, 203.85 feet to the Northwesterly boundary of County Road Survey No. 821 (Highland Drive) as described in Parcel 2 in deed to the County of San Diego, recorded April 21, 1949, as Document No. 35,757 in Book 3179, Page 154 of Official Records; being a point on the arc of a 165.88 foot radius curve concave Northwesterly, a radial line of said curve bears South 13°38'13" East to said point; thence along said Northwesterly boundary as follows: Westerly along the arc of said curve through a central angle of 10°17'13" a distance of 29.78 feet to the beginning of a reverse 170.00 foot radius curve; Southwesterly along the arc of said curve through a central angle of 52°40'00" a distance of 156.27 feet to the point of tangency in the Southeasterly line of said Lot 6; and along said Southeasterly line tangent to said curve South 33°59'00" West, 37.91 feet to the most Southerly corner of said Minton's land; thence along the Southwesterly line of said Minton's land North 56°01'00" West, 115.00 feet to a line which bears South 33°59'00" West from the True Point of Beginning; thence North 33°59'00" East, 195.73 feet to the TRUE POINT OF BEGINNING.

ALSO that portion of Lot 6 adjoining the above described land as shown on said Record of Survey Map No. 4270 that lies Westerly of the Southeasterly prolongation of the Northeasterly line of the above described land.

Part 5

Study the wording and verify closure of the specified legal description and make corrections as needed.

P9-18 Beginning at the one-quarter corner on the North line of said Section 13; thence East 111.65 feet; thence South 659.17 feet; thence South 25°35' East 195.00 feet to a 5/8-inch iron rod; thence South 56° West 110.00 feet to a 5/8-inch iron rod; thence South 34° East 120.79 feet to a 5/8-inch iron rod; thence South 19°30' East 50.42 feet to a 5/8-inch iron rod; thence South 40°32' East 169.38 feet to a 5/8-inch iron rod; thence South 49°29' West 100.00 feet to a 5/8-inch iron rod; thence South 65°00'50" West 51.89 feet to a 5/8-inch iron rod; thence South 52°21'30" West 125.00 feet to a 1/2-inch iron pipe, being the true point of beginning; thence continuing South 52°21'30" West 124.91 feet to a 1/2-inch iron pipe on the arc of a circle with a radius of 50.0 feet, the center of which bears North 22°01'30" West 50.00 feet from said last-mentioned iron pipe; thence Northeasterly along the arc of said circle, through an angle of 69°53'29", 60.99 feet to a 1/2-inch iron pipe; thence North 88°05'01" East 51.00 feet to a 1/2-inch iron pipe; thence South 39°55'35" East 80.00 feet to the true point of beginning. ALSO known as Lot 6, Block 3, Chateau Riviere, in Modesto, California.

Part 6

Draw the plans shown in the specified figure. Use an appropriate sheet size, drawing scale, border, title block, and as many of the site plan requirements described in this chapter as possible.

P9-19 Figure 9-9.

P9-20 Figure 9-15.

P9-21 Figure 9-21.

P9-22 Figure 9-26.

Part 7

Given the partial subdivision plat shown in Figure 9-3, select one or more fully displayed lots, or your instructor will assign a specific lot or lots. Write the complete legal description for the selected lot or lots.

P9-23 See Figure 9-3

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CHAPTER

10

Horizontal Alignments

Learning Objectives

After completing this chapter, you will be able to:

- Define horizontal alignment.
- Lay out the horizontal centerline of a route.
- Define types of curves and identify the components of a simple curve.
- Construct simple curves.
- Describe horizontal alignment design and drafting with civil CADD software.

Key Terms

Alignment
Horizontal alignment
Vertical alignment
Full station
Plus station
Horizontal curve
Simple curve
Circular curve
Compound curve
Reverse curve
Spiral curve
Transition curve
Back tangent
Rear tangent
Forward tangent
Point of intersection (PI)
Intersecting angle (I)
Right-hand curve
Left-hand curve
Radius (R)
Point of curve (PC)
Point of curvature
Point of tangency (PT)
Length of curve
Curve length
Tangent distance (T)
Delta angle (Δ)
Central angle
Included angle
Long chord (LC)
External distance (E)
Middle ordinate (M)
Degree of curve (D)
Point of reverse curve (PRC)

The term **alignment** can be used in mapping, civil engineering, and surveying to describe the horizontal or vertical characteristics of a route such as a road, highway, railway, or utility line. **Horizontal alignment** defines the position and direction of a route on a horizontal plane, or plan view. For example, horizontal alignment explains the horizontal curves in a road as seen on a site plan. **Vertical alignment** defines the vertical form, or change in elevation, of a route on a vertical plane, or profile. For example, vertical alignment specifies the straight inclines and vertical curves in a road as displayed on a profile. This chapter explores the basic principles of establishing horizontal alignments. Chapter 11 explains profiles and vertical alignments.

Plan Layout

The layout of a proposed route, such as a road, highway, light rail track, or sewer line, usually begins on a contour map or an aerial photograph. Designers and engineers, with input from government officials, use maps and information gathered from preliminary field studies to determine the overall extents of the project, including the location and limits of the proposed route and right-of-way boundaries. The ultimate design begins with planning a field survey and locating utilities. Surveyors then conduct a topographic survey to map the corridor with enough detail to produce an accurate triangulated irregular network (TIN) as explained in Chapter 5. The surveyors generate as many points as are needed to produce a digital terrain model (DTM) with appropriate detail for engineers and drafters to use to lay out the route using CADD software.

Centerline (Route) Survey

Horizontal alignments are critical to the design of routes such as the highway shown in Figure 10–1. This chapter uses roadway centerline lay out to explore horizontal alignments. Much of the content can be applied to a plan view of any route such as the plan view of a waterline shown in Figure 10–2. Figure 10–3 shows a basic plan layout for the centerline of a roadway. The plan view usually shows all features in the corridor including trees, fences, buildings, other roads, and cultivated areas. The centerline, or transit line, of a route survey is drawn using bearings and distances. Distance is measured along an alignment in the form of stationing. Stationing locates station (STA) points every 100' (30 m) from the beginning of the project. 0+00 designates the beginning of the project. A **full station** is 100' (30 m). For example, 10+00 is a full station 1,000' from the beginning. A **plus station** specifies a point between full stations. For example, 15+68.61 is a plus station that indicates a point 1,568.61' from the beginning.

When referring to a point that is not directly located on the alignment, offset is used in combination with station. For example, a manhole that is 1,250.57' beyond the beginning of the alignment and 15' away from the alignment is expressed as station 12+50.57, offset 15'. Sign is also important when expressing offset as negative values refer to left offsets and positive refer to right offsets. For the



Figure 10-1. An aerial photograph of a highway shows the horizontal design characteristics required to define the position and direction of the route.
(TB[Picnic]/Fotolia)

example of the manhole at station 12+50.57 with an offset of 15', the manhole is on the right side of the road because the offset value is positive. To define left and right, imagine standing on the alignment and looking in the direction of increasing station. When using the metric system, station numbers are specified as the distance from

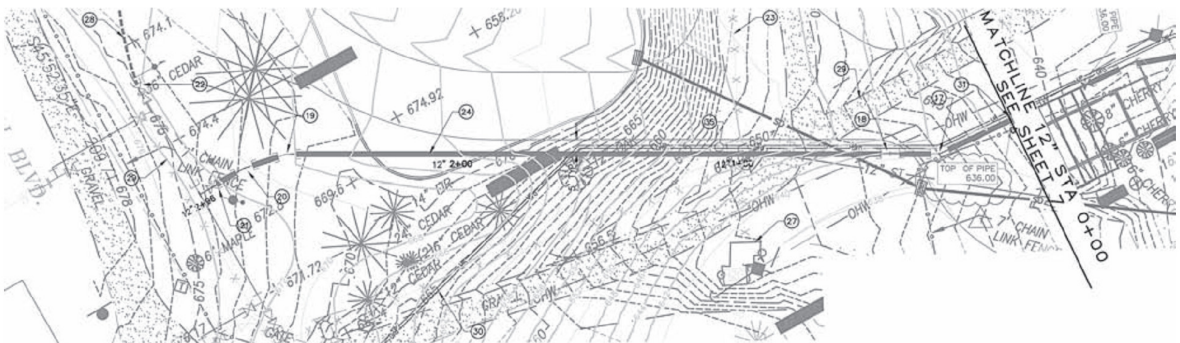


Figure 10-2. A drawing of a waterline created from data collected during a route survey.
(Courtesy of PACE Engineers, Inc.)

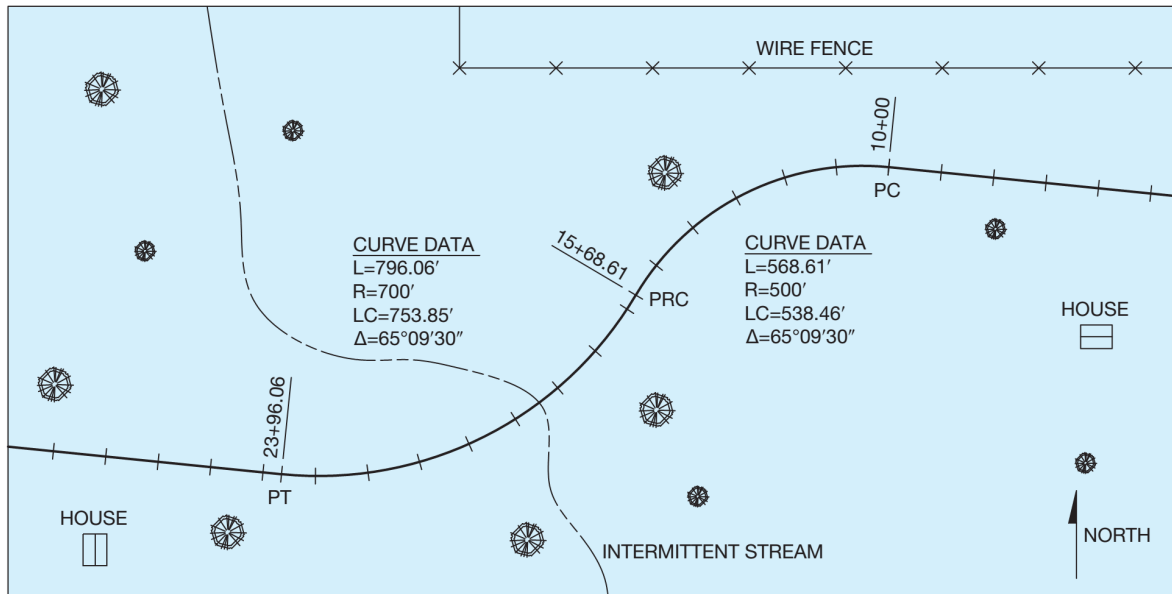


Figure 10-3. A simple depiction of the centerline layout of a highway. This example includes a reverse curve.

the point of beginning, without using the plus system. Notice that the road shown in Figure 10-3 is designed to include curves. Curves are explained in the next section of this chapter.

Note: The design of roadways is a specialized branch of civil engineering related to the proper location and format of roadway features according to specific standards and codes. In the United States, the Federal Highway Administration (FHWA), state and local agencies, and the American Association of State Highway and Transportation Officials (AASHTO) have defined standards and practices relating to roadway design. Roadway drawings provide all necessary roadway design criteria from the intended speed of vehicles traveling on the road to the dimensions of curves.

Horizontal Curves

The alignment of the route of a roadway is defined by a sequence of horizontal and vertical curves. Curves are a critical element of roadway design. A **horizontal curve** is a geometric feature that occurs when a route changes direction or alignment. Curves are classified as simple, compound, reverse, or spiral (see Figure 10-4). A **simple curve**, also known as a **circular curve**, is an arc of a circle with a constant radius (R). The radius of a curve determines how abrupt, or sharp, or gentle, or flat, the curve is. The larger the radius of the curve is, the gentler the curve will be. A simple curve is usually tangent to straight lines and is generally the most common type of curve.

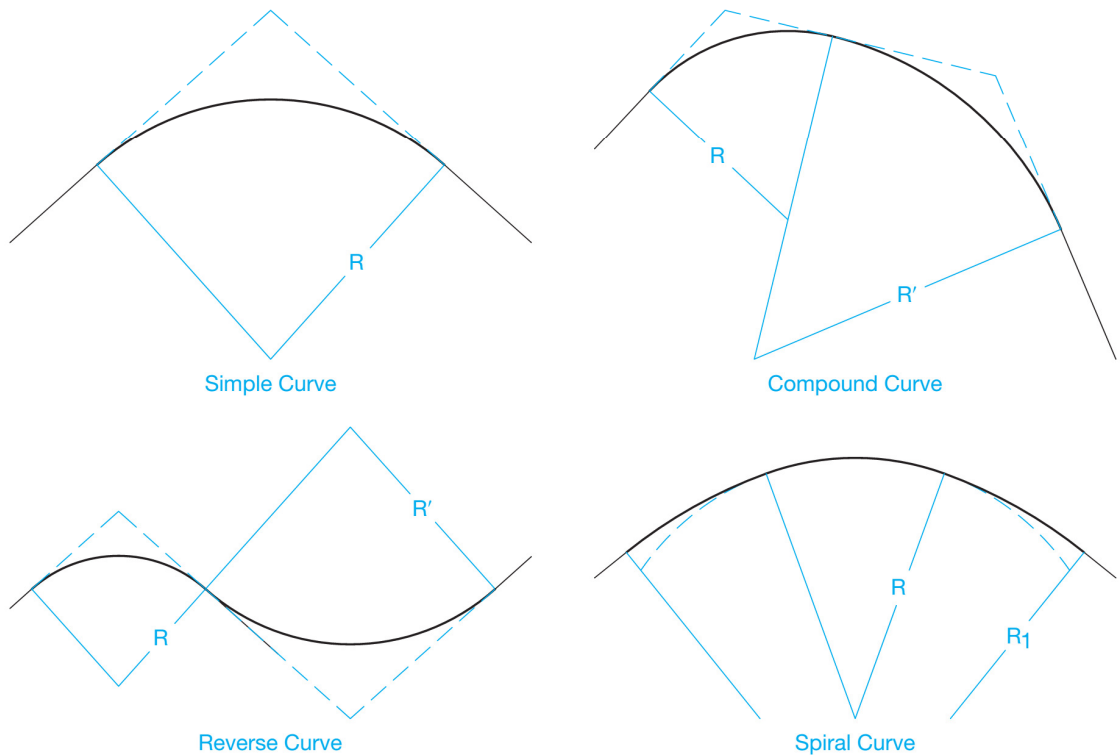


Figure 10-4. Curves are classified as simple, compound, reverse, or spiral.

A **compound curve** includes two simple curves with different radii joined together and curving in the same direction. Compound curves are used whenever it is necessary to change the radius of a curve, such as curving around obstacles, boundaries, or changes in terrain. A **reverse curve** includes two simple curves with the same or different radii joined together and curving in opposite directions. Reverse curves are used whenever it is necessary to reverse the direction of an alignment but are avoided when possible in roadway design because of safety factors. A **spiral curve**, also known as a **transition curve**, is a curve defined by a constantly changing radius. A spiral curve is often used to create a smooth transition between a straight line and a simple curve or between simple curves in a compound curve. Spiral curves are most common in the design of railways and for some highway applications.

Components of a Simple Curve

The information needed to construct a circular curve may appear as dimensions and specific notes on a drawing and/or in a curve data table. Figure 10-5 shows a portion of a subdivision plat with notes used to label each curve and provide the curve length (L). Additional data for each curve is presented in a table. Figure 10-6 shows the elements of a simple curve. The curve forms between and is tangent to straight alignments AB and BC. The tangent line before the beginning of the curve is known as the **back tangent** or

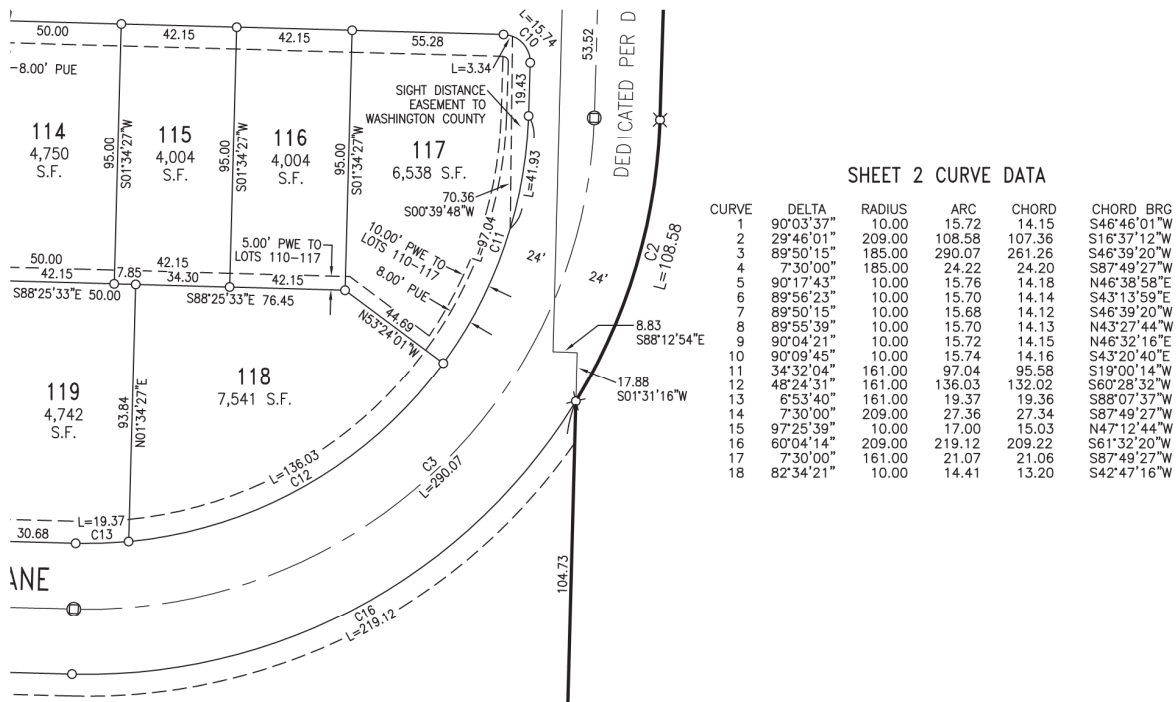


Figure 10-5. A portion of a subdivision plat with notes used to label each curve and provide the curve length (L). Each curve is keyed to a table with additional curve data.
(Courtesy of Otak, Inc.)

rear tangent. The tangent line after the end of the curve is known as the **forward tangent**. The direction of the route survey determines the back and forward tangents. The **point of intersection (PI)** is the point where the back and forward tangent extensions intersect. A PI is the vertex (V), or junction, of two centerlines of different bearings. The **intersecting angle (I)** is the exterior deflection angle at the PI, between the back tangent and the forward tangent. The curve shown in Figure 10-6 is an example of a **right-hand curve** because the deflection angle is to the right. A curve with a deflection angle to the left is called a **left-hand curve**.

Radius (R) is the radius of the circle of which the curve is an arc. To find the center point of the arc (O), project a line perpendicular to the centerline and measure the distance on this line. The **point of curve (PC)**, or **point of curvature**, is the point where the curve begins. The alignment of the route changes from a straight line to a curve at the PC. The back tangent is tangent to the curve at the PC. The station value is written at the PC. The **point of tangency (PT)** is the point at the end of the curve where the curve is tangent to the forward tangent. The alignment of the route changes from a curve to a straight line at the PT. The station value is written at the PT.

The **length of curve (L)**, or **curve length**, is the centerline distance along the arc from the PC to the PT. The **tangent distance (T)** is the distance along the tangents from the PI to the PC or PT. The tangent distances are equal on a circular curve. The **delta angle (Δ)**, also known as the **central angle** or **included angle**, is the angle of

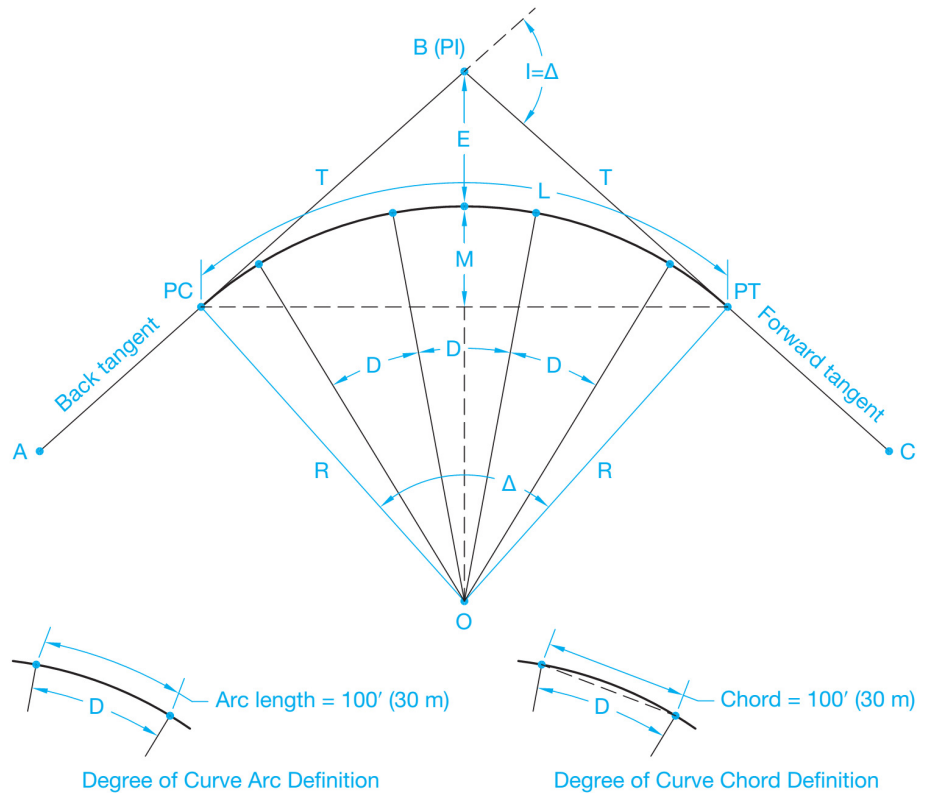


Figure 10-6. Components of a simple curve.

the curve formed by two radii from the center point of the arc (O) to the PC and PT. The delta angle equals the intersecting angle. The **long chord (LC)** is the chord distance from the PC to the PT. Curve data often includes the bearing angle of the LC. The **external distance (E)** is the distance from the PI to the midpoint of the curve, and bisects the interior angle at the PI. The **middle ordinate (M)** is the distance from the midpoint of the curve to the midpoint of the LC. Extend the middle ordinate to bisect the delta angle. The **degree of curve (D)** is the angle of the 100' (30 m) arc or chord that connects station points. The degree is measured from the previous station. Arc definition or chord definition can be used to define the degree of curve. The **point of reverse curve (PRC)**, is the point at which one curve ends and the next curve of a reverse curve begins (see Figure 10-3).

Curve Layout

Use the components of a simple curve to lay out a curve given specified alignment and curve data. For example, construct a circular curve between two straight horizontal alignments given bearings, distances, and curve radii (see Figure 10-7a). Notice how the curve data establishes centerlines and PIs. To find the center point of the radius, measure the radius perpendicularly from each leg of the road to the inside of the curve. Then, draw a line parallel to each leg through the radius point just measured. The intersection of these two parallel

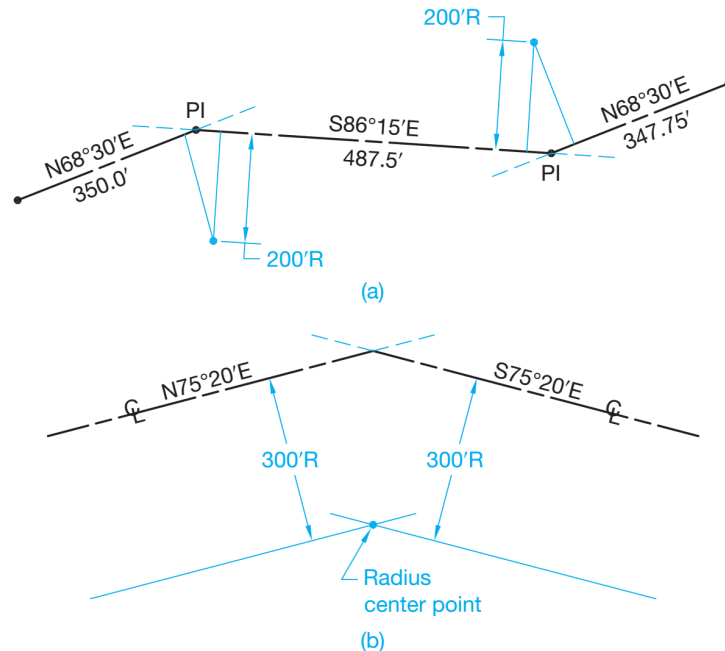
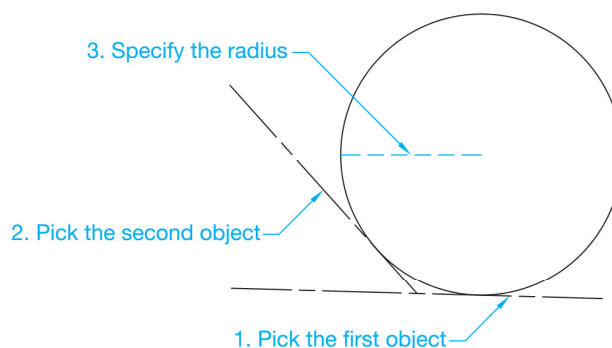


Figure 10-7. (a) Highway curve layout using bearings, distances, and curve radii. (b) A method for locating the radius center point of a highway curve.

lines is the center point for the radius curve (see Figure 10-7b). You can now construct the curve and road outline, using the radius point.

Basic CADD object commands such as circle and arc commands provide several options for drawing circular curves. Select the appropriate option based on the information you know about locating and constructing the curve. For example, AutoCAD's CIRCLE command includes a Tan, Tan, Radius option that allows you to pick two objects tangent to a circle and specify the circle radius. When using this option, pick one of the straight road sections followed by the other straight road section and then specify the given curve radius (see Figure 10-8). Once the centerlines of the road have been plotted and the curves are laid out, the width of the road, right-of-way, and other

Figure 10-8. Using a basic CADD object command option to construct a circle tangent to existing lines using a given radius.



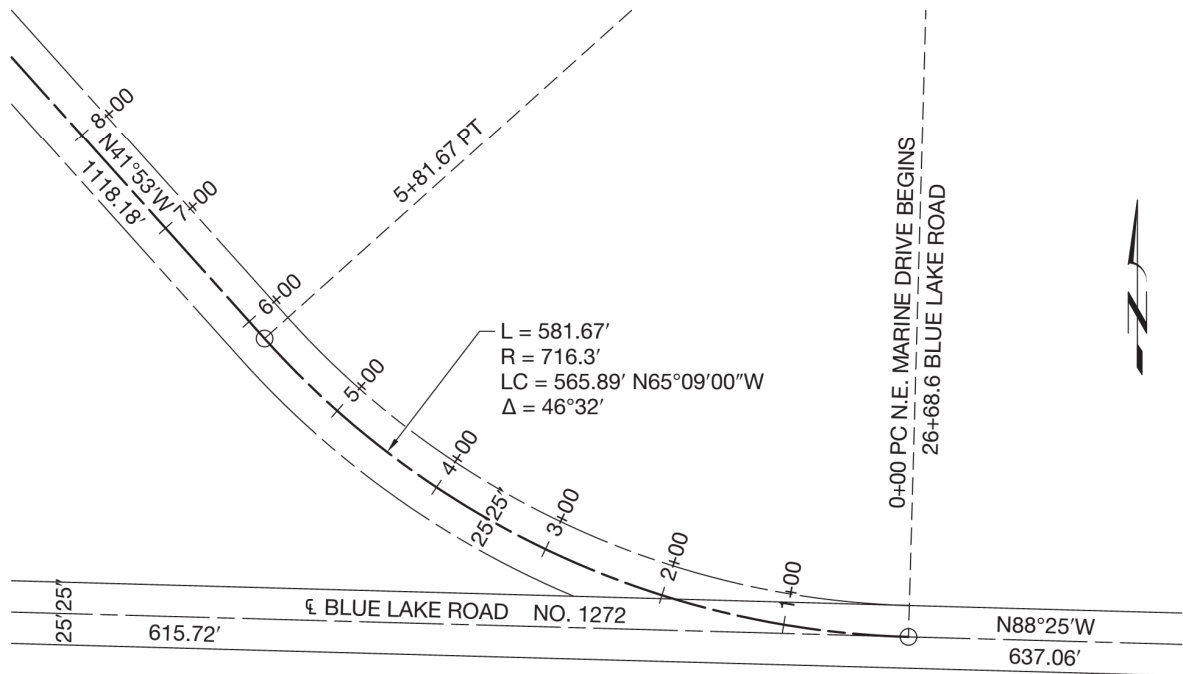


Figure 10-9. A portion of a proposed roadway beginning at an existing road. Curve data is given in a specific note to the centerline of the curve.

roadway features can be drawn by measuring from the centerline. Figure 10-9 shows a portion of a proposed roadway drawing. The beginning of the project is a curve originating at an existing road.

Horizontal Alignments with Civil CADD

In a CADD environment, roads are designed in three stages. The first stage is the horizontal layout, or alignment; the second stage is the vertical layout, or profile; and the third stage is the cross section perpendicular to the profile. The alignment is the two-dimensional (2-D) path that the road is to follow and often represents the centerline of the road, although that is not a requirement. Road centerline geometry consists of straight line segments, or tangents; simple, compound, and reverse curves; and in some cases spiral curves.

The alignment serves as a reference, or baseline, for the design and construction of the road and related features such as drainage, signage, and legal boundaries. Figure 10-10 shows the intersection of two horizontal alignments. The black lines represent alignments that define the centerlines of future roads. The black text includes stationing and annotation of several key geometric features of the alignments.

Creating Alignments

Perhaps the most important geometric rule governing alignments is that all of the segments that form the alignment remain tangent to one another. For this reason, most civil CADD packages possess

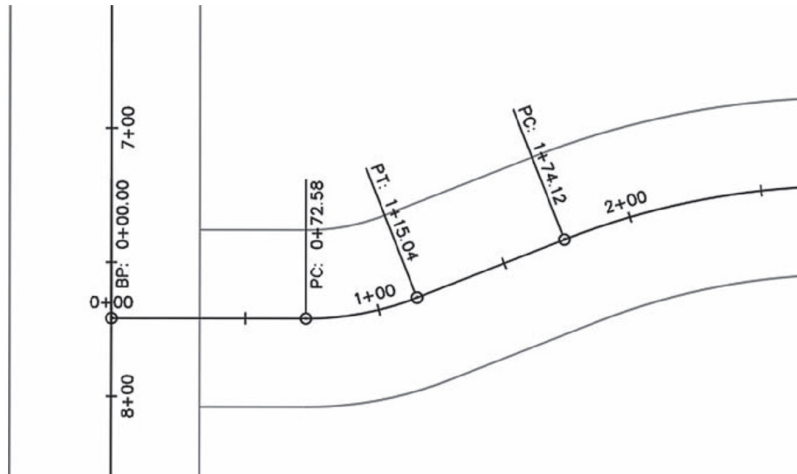


Figure 10-10. The intersection of two horizontal alignments.
(Courtesy of Eric Chappell and Autodesk, Inc.)

alignment functionality that automatically respects this need for tangency while creating alignments. For example, a typical civil CADD package requires that the user pick points representing PIs. The software automatically fills in tangents, curves, and possibly even spirals based on design rules or assumptions. The alignment shown in Figure 10-11 was created in AutoCAD Civil 3D using an alignment command and clicking points 1 through 4. The curves and stationing were added automatically.

Alignments are often created from existing drawing geometry, such as a road centerline constructed through a series of offsets, newly drawn elements, arcs, and fillets. This geometry, comprised of more basic elements, can typically be converted to an alignment object using specialized commands or functions. The newly created alignment then possesses the additional functionality characteristics of an alignment object.

Editing Alignments

As with creating alignments, maintaining tangency is an important part of the extra functionality built into the alignment objects of most CADD packages. Alignments can typically be edited using graphical, command-based, and numerical approaches. A typical graphical editing approach consists of clicking and dragging a point on the alignment to change the location of a PI, radius of a curve, or position of a PI. Figure 10-12 shows graphically modifying the location of a PI in AutoCAD Civil 3D.

Examples of a command-based edit are adding a PI or removing a curve. Figure 10-13 displays adding a PI by launching the Insert PI command in AutoCAD Civil 3D. A numerical edit can consist of entering a value representing the radius of a curve or the length of a tangent. Numerical edits are completed in spreadsheet format for a



Figure 10-11. An alignment created in AutoCAD Civil 3D using an alignment command and clicking points 1 through 4.
(Courtesy of Eric Chappell and Autodesk, Inc.)

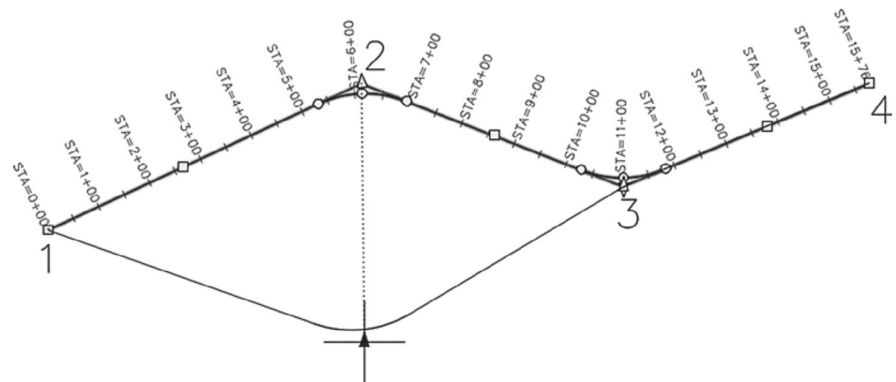


Figure 10-12. Graphically editing the location of a PI in AutoCAD Civil 3D.
(Courtesy of Eric Chappell and Autodesk, Inc.)

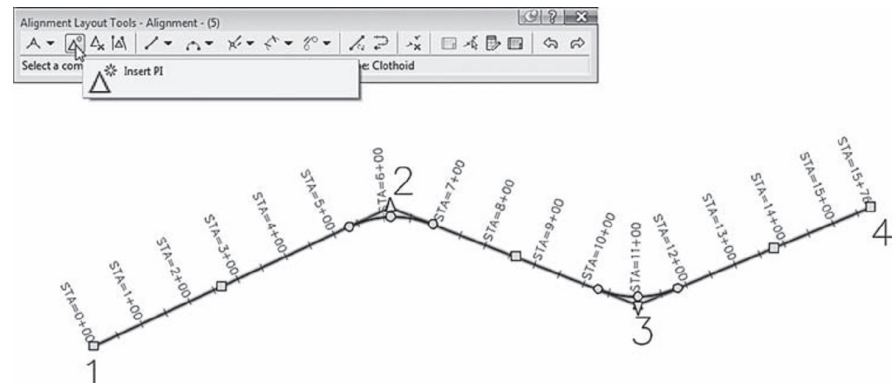


Figure 10-13. Adding a PI by launching the Insert PI command in AutoCAD Civil 3D.
(Courtesy of Eric Chappell and Autodesk, Inc.)

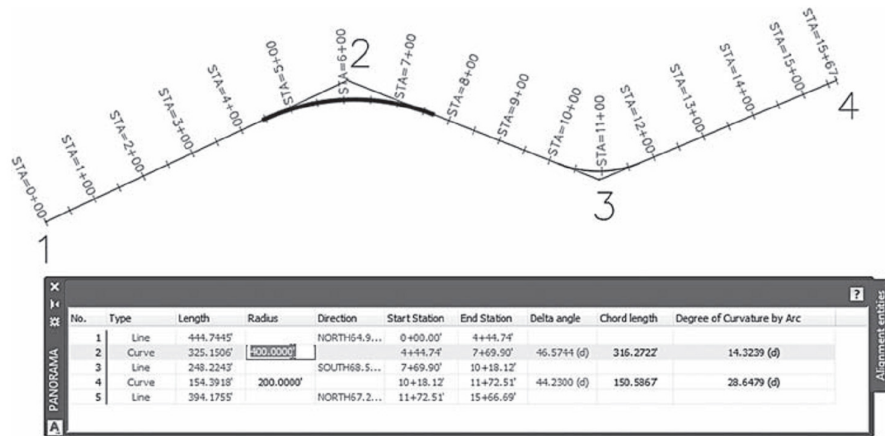


Figure 10-14. Numerically editing a curve radius in AutoCAD Civil 3D.
(Courtesy of Eric Chappell and Autodesk, Inc.)

single alignment component, or in some cases, for the entire alignment. Figure 10-14 displays numerically editing a curve radius in AutoCAD Civil 3D.

Labeling Alignments

Most quality CADD programs automate the drawing labeling process as much as possible. For alignments, drafters and designers label the alignment and any features that reference the alignment. Stationing typically behaves as though one labeling entity represents all of the station values, rather than the user individually placing each tick mark and value. Stationing annotation should also move and update automatically as the alignment is modified. Alignment labeling needs often extend beyond the stations to include key geometric points especially those relating to curves such as PCs, PTs, PRCs, or PCCs. Figure 10-10 shows some common PC and PT labels that indicate the locations of these key points along with calling out the stations where the points occur. In addition to labeling the alignment itself, a user may want to label the locations of features using station-offset notation, with the alignment as a baseline. In Figure 10-15, for example, the sanitary sewer manhole location is expressed using station and offset notation.

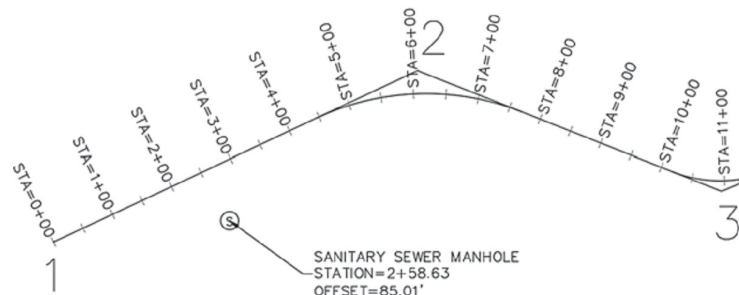


Figure 10-15. Labeling the location of a sanitary sewer manhole.
(Courtesy of Eric Chappell and Autodesk, Inc.)

The Extended Purpose of an Alignment

Perhaps the most important role that the alignment serves is that it provides the basis for the other two phases of road design in a CADD environment: the profile and the cross section. You will learn about profiles and cross sections later in this textbook, but for now you should know that neither profiles nor cross sections can exist without first creating an alignment. The alignment serves as the baseline, also known as the backbone, of the road design. The alignment also carries through to construction. The first set of stakes that will go in the ground on a typical road construction site are the 100-foot stations along the road centerline alignment.

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Answer the following questions.

- 10-1** Explain the difference between horizontal and vertical alignment.
- 10-2** List three civil engineering projects that require centerline (route) survey.
- 10-3** What is the distance between station points along a route survey?
- 10-4** When using the plus system of stationing for centerline layout what does 0+00 designate?
- 10-5** A full station of 3+00 is how far from the beginning of the project?
- 10-6** A plus station of 36+7.95 is how many feet from the beginning of the project?
- 10-7** A plus station of 6+23.1 is how many feet from the full station 6+00?
- 10-8** List the four general types of curves.
- 10-9** What is the abbreviation for radius?
- 10-10** Explain the general purpose of a compound curve and a reverse curve.

Part 2

Identify the abbreviation for and define the following components of a simple curve.

10-11 Point of intersection

10-12 Intersecting angle

10-13 Point of curve

10-14 Point of tangency

10-15 Length of curve

10-16 Included angle

10-17 Long chord

10-18 Degree of curve

Part 3

Study the portion of the subdivision plat shown in Figure R10-1 to answer the following questions. The plan is also available for download and viewing. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Chapter 10 Plan.pdf.

10-19 The drawing scale is _____ and north is toward the _____ of the sheet.

10-20 The drawing is sheet _____ of _____ total sheets.

10-21 Tract 'P' is _____ acres, and is north, south, east, or west of N.W. 159th Avenue: _____?

- 10-22** Tract 'O' is _____ wide, _____ square feet, and is north, south, east, or west of Lot 108: _____?
- 10-23** PUE denotes _____, PWE denotes _____, and S.F. denotes _____.
- 10-24** Curve 3 has an arc length of _____ and a radius of _____.
- 10-25** There is a 5.00' _____ (__) along the south property lines, and an 8.00' _____ (__) along the north property lines of Lots _____ through _____.
- 10-26** The west property line of Lot 105 is _____ long, bearing _____. The north property line of Lot 105 is _____, bearing _____.
- 10-27** The dashed line offset from the north property lines of Lots 86 through 100 indicates the location of an _____ (___).
- 10-28** NW Linder Street is a two-lane street _____ wide with a center-line _____ long, bearing _____.
- 10-29** The distance from the west property line of Lot 109 is _____ from the centerline of NW 159th Avenue. NW 159th Avenue is _____ wide.
- 10-30** Curve _____ is located on the south property line of lot 118.
- 10-31** Curve 2 has an arc length of _____, a delta angle of _____, a radius of _____, a long chord of _____, and a chord bearing of _____.
- 10-32** Curve _____ is the smallest curve on the sheet with a _____ radius, _____ arc length, and _____ long chord.

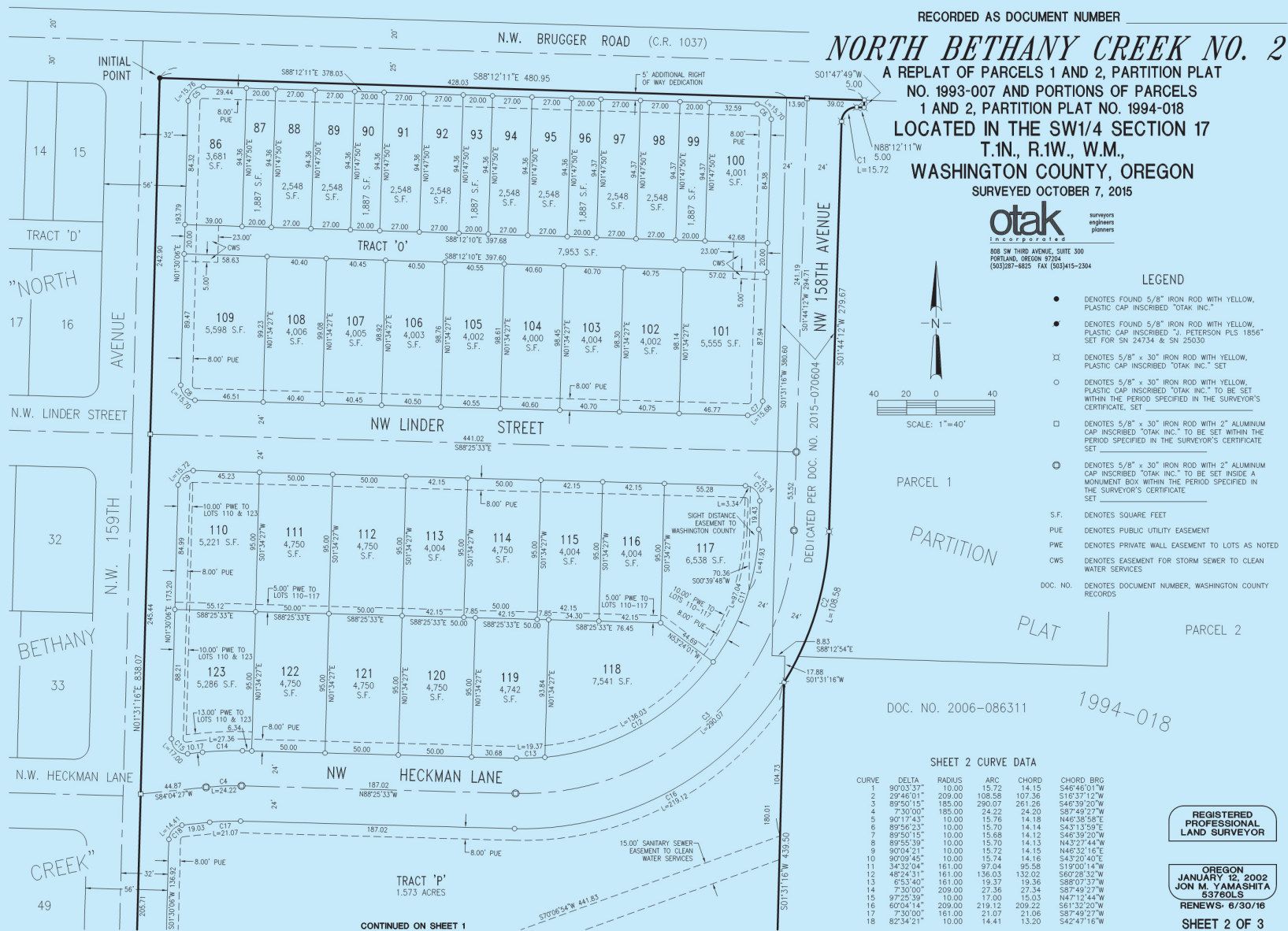


Figure R10-1.
(Courtesy of Otak, Inc.)

PROBLEMS

Follow the specific instructions to complete each problem.

P10-1 Lay out a 40' wide road on the site shown in Figure P10-1. Plot the centerline using the following information and then construct the curves and road outlines. Label all points, bearings, and radius curves. Show centerline stationing along the road. Plot the drawing at a scale of $1'' = 200'$ on an ANSI A size sheet. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 10-1.dwg file to reference the plan.

- Point A is 710' west from the right edge of the map on the centerline of Beaver Creek Road.
- Point B is 550' from point A, bearing $N24^{\circ}30'E$, and is the point of intersection (PI) of a 200' radius (R) curve.
- Point C is 620' from point B, bearing $N39^{\circ}25'W$, and is the PI of a 300' R curve.
- The road continues due north from point C.

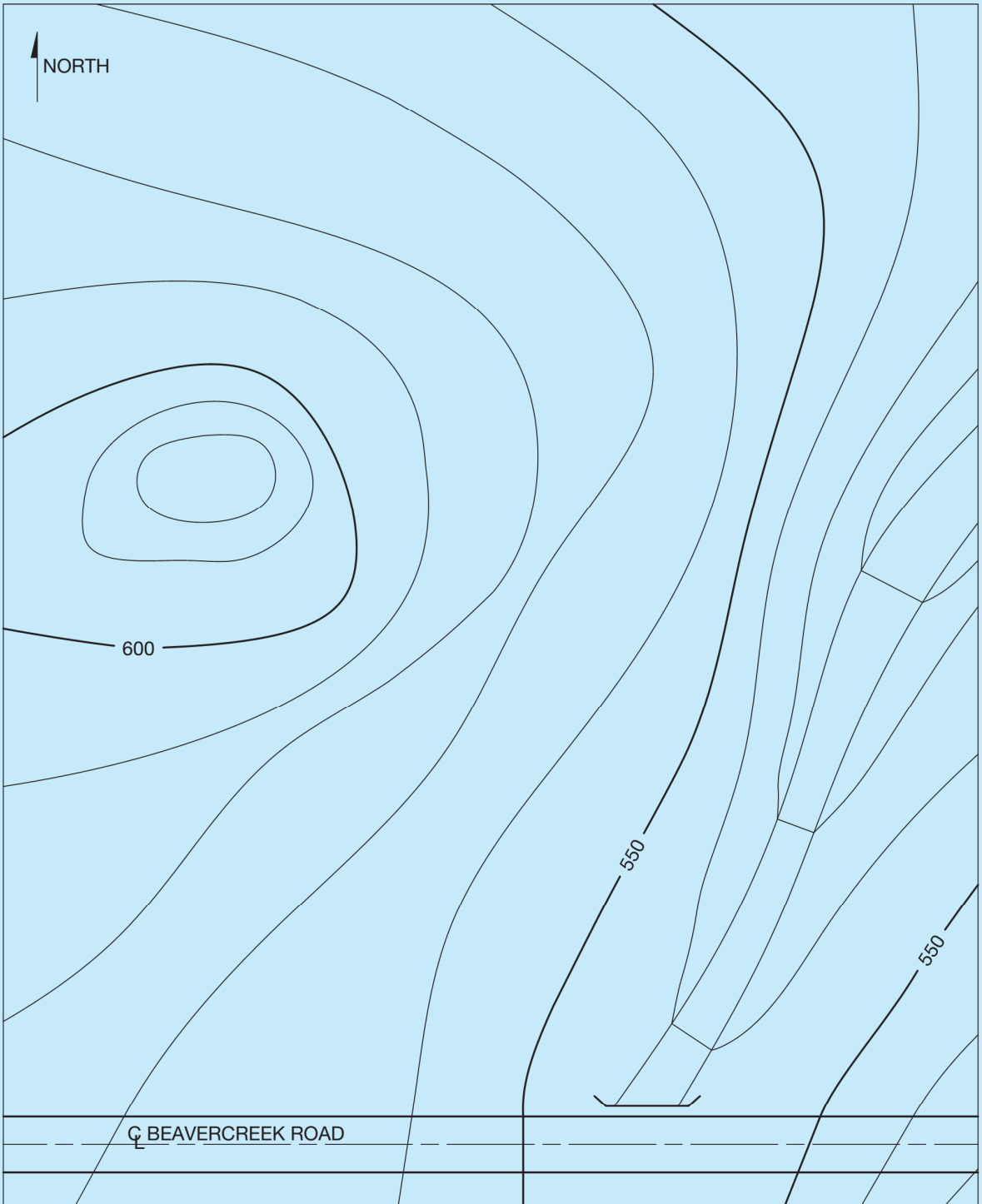
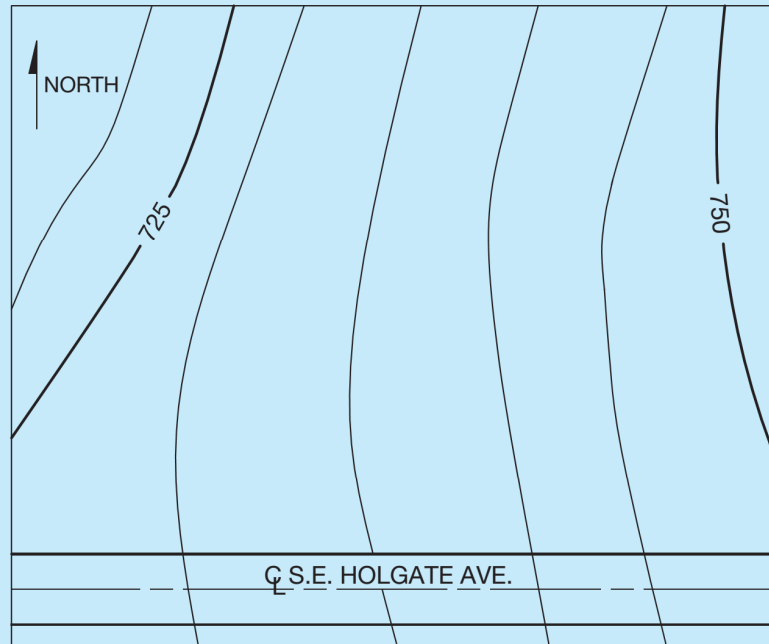


Figure P10-1.

P10-2 Lay out a 40' wide street on the site shown in Figure P10-2. Plot the centerline using the following information and then construct the curves and road outlines. Label all points, bearings, and radius curves. Show centerline stationing along the street. Plot the drawing at a scale of 1" = 50' on an ANSI B size sheet. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 10-2.dwg file to reference the plan.

- Point A is 100' east from the left edge of the map on the centerline of S.E. Holgate Ave.
- Point B is 110' due north from point A and is the point of curve (PC) of curve 1 (C1) with a delta angle (Δ) of 30° and a 150'R.
- Point C is the point of tangency (PT) of C1.
- Point D is 170' from point C, bearing N30°E and is the PC of curve 2 (C2) with a Δ of 60° and a 100'R.
- Point E is the PT of C2.
- Point F is 160' due east from point E and is the PC of curve 3 (C3) with a Δ of 90° and a 120'R.
- Point G is the PT of C3.
- Point H is due south from point G to the centerline of S.E. Holgate Ave.

Figure P10-2.



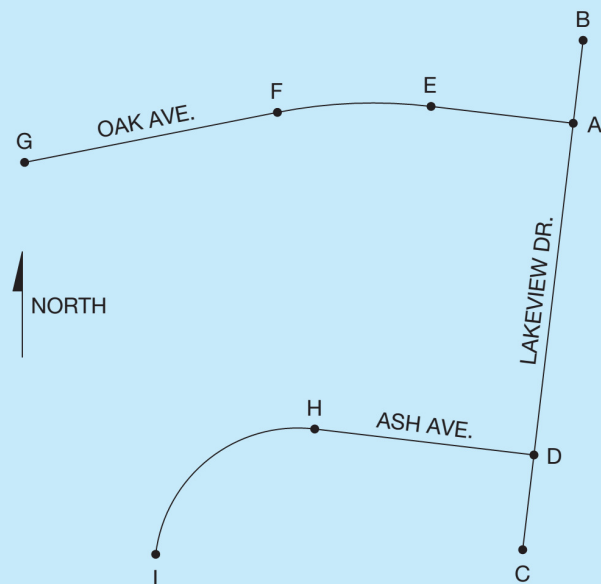
P10-3 Use the finished drawing from Problem P8-5 to complete this problem. Layout a 20' wide road using the following information and then construct the curves and road outlines. Label all points, bearings, and radius curves. Show centerline stationing along the road.

- Point A is 225' east from station A 12+00 along the bottom of the map.
- Point B is 756' from point A, bearing N26°14'E, and is the PI of a 300'R curve.
- The road continues N13°15'W to top of map from point B.
- The road has 6' wide shoulders.
- The elevation of the road centerline is 530'.

- P10-4** Create a partial street layout map using the information shown in Figure P10-4. Draw all features listed in the following information. Label all points and streets. Plot the drawing at an appropriate scale on an appropriate sheet size.

Figure P10-4.

Line Data			
Line	Bearing	Distance	
AD	S6°45'32"W	280'	
DC	S6°45'32"W	80'	
AB	N6°45'32"E	70'	
AE	N83°14'28"W	120'	
FG	S78°48'43"W	216'	
DH	N83°14'28"W	185'	
Curve Data			
Curve	Radius	Delta Angle	Length
EF	413'	17°56'49"	129.37'
HI	120'	90°	188.50'
Street Data			
Street width 40' (20' from centerline to edge of pavement (EOP))			
Curb width 8" from EOP to grass strip			
Grass strip from curb to sidewalk 4'			
Sidewalk width 5'			
Sidewalk radius at street intersections 15'			



P10-5 Use the survey data given in Figure P10-5 to plot contour lines at a 10' contour interval. Use proper methods of contour line interpolation and the specified contour interval. Use appropriate lineweights to represent each type of contour line. Label all index contours, and use a 1/8" plotted text height for all labels, notes, and dimensions. Layout roads on the map using the point of intersection method and the following road data. Label curves with the radius, delta angle, and length of curve. Plot the final drawing at a 1" = 100' scale on an architectural C size sheet. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 10-5.dwg file to reference point data.

- Point A is 217.219' north from the lower-left corner of the grid and defines the first point of the first road.
- Point B is 135.14' from point A, bearing N68°56'59"E, and is the PI of a 300' R curve.
- Point C is 449.07' from point B, bearing N87°26'51"E, and is the PI of a 200' R curve.
- Point D is 337.54' from point C, bearing N47°25'53"E, and is the PI of a 350' R curve.
- Point E is 281.75' from point D, bearing N19°33'9"E, and is the PI of a 300' R curve.
- The road continues N23°56'23"E to the edge of the map.
- Point G defines the first point of a road that intersects the previous road. Point G is 284.84' from point F, bearing N15°42'41"W, and is the PI of a 240' R curve.
- Point H is 243.09' from point H, bearing N66°28'17"W, and is the PI of a 200' R curve.
- The road continues N78°44'6"W to the edge of the map.
- The roads are 24' wide with a 4' wide shoulder on each side.

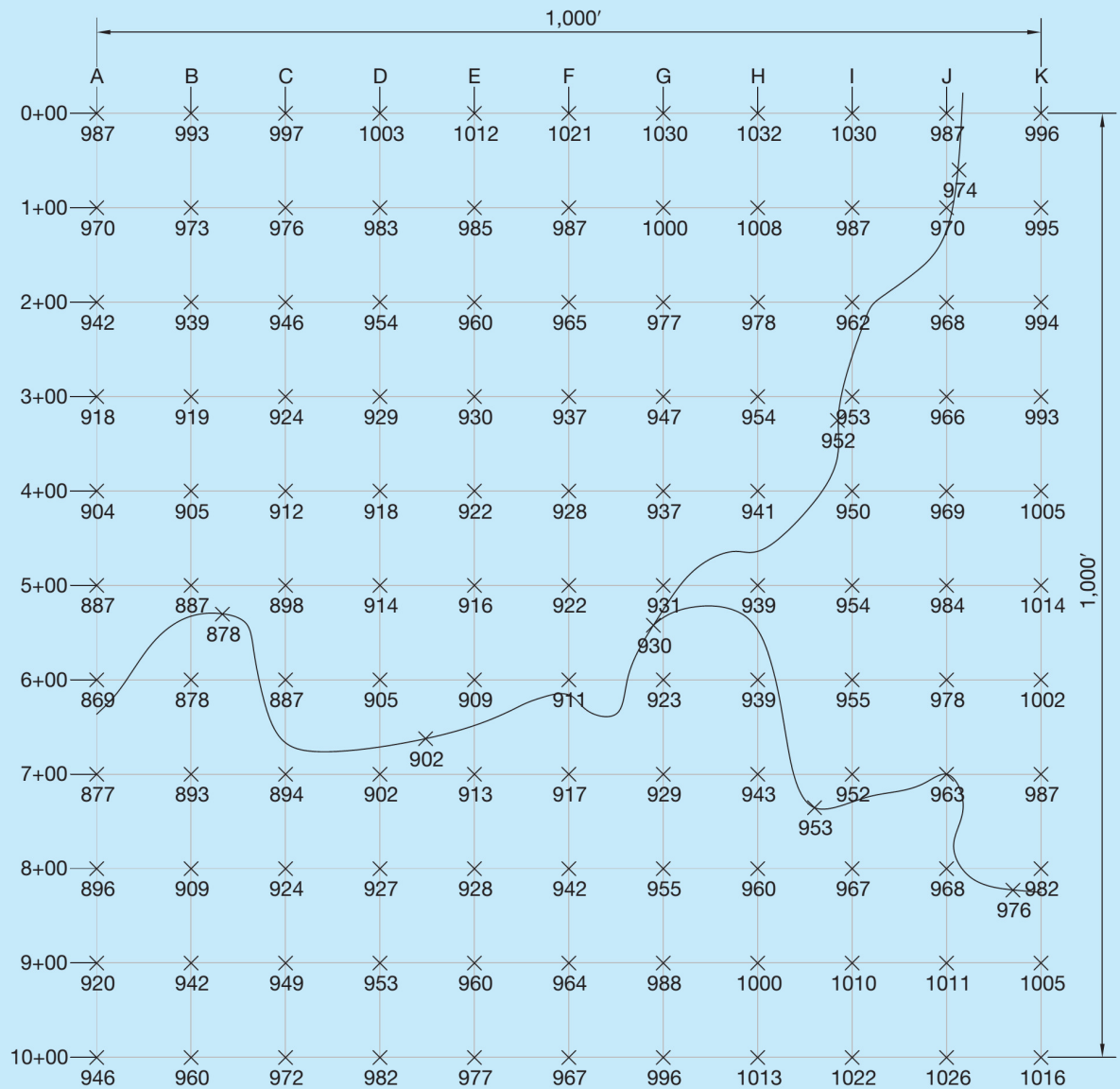


Figure P10-5.

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CHAPTER

11

Profiles

Learning Objectives

After completing this chapter, you will be able to:

- Explain the profile leveling process.
- Read plan and profile drawings.
- Construct profile drawings from survey data.
- Identify the components of vertical curves.
- Calculate tangent distances for vertical curves.
- Construct vertical curve profile drawings.
- Describe plan and profile design and drafting with civil CADD software.

Key Terms

Cross section view
Cross section
Profile
Vertical alignment
Profile leveling
Backsight (BS)
Intermediate foresight (IFS)
Full station
Plus station
Turning point (TP)
Foresight (FS)
Plan and profile
Grading
Cutting-plane line
Grade (GR or GRD)
Invert elevation (IE)
Percent slope (S)
Percent grade
Vertical alignment
Vertical curve
Sag curve
Crest curve
Summit curve
Ordinate

Once plan drawings are available, profile and cross section drawings are created to show the side view, or elevation, of plan view features. A **cross section view**, or **cross section**, is a view that cuts through an area to show detail that cannot be clearly identified in the plan view. A **profile** is a cross section of a portion of land or along the length of a linear feature such as a road, sewer line, power line, or stream. Together, plans, profiles, and cross sections provide the design information needed to lay out a civil engineering project. This chapter explores the basic principles of establishing profiles and vertical alignments. **Vertical alignment** defines the vertical form, or change in elevation, of a route on a vertical plane, or profile. You will learn more about other types of cross sections later in this textbook.

Profile Layout

The layout of a proposed civil engineering project such as a building site, road, or utility line begins with a plan, or horizontal, layout of the area to be developed. Surveyors eventually conduct a topographic survey to map the area with enough detail to produce an accurate triangulated irregular network (TIN) as explained in Chapter 5. The surveyors generate as many points as are needed to produce a digital terrain model (DTM) with appropriate detail for engineers and drafters to use to lay out the plan of the area using CADD software. The resulting design is then used as the data source to generate profiles. The following information is valuable information about the process of profile leveling and gives you important background knowledge.

Profile Leveling

Surveyors use profile leveling to establish or check the elevation characteristics along the route of a civil engineering project such as a highway, utility line, railroad, or canal. **Profile leveling** is similar to standard differential leveling but additional intermediate shots are taken along the centerline of the route. Figure 11-1 shows a basic plan layout of a typical profile leveling setup along the centerline of a route.

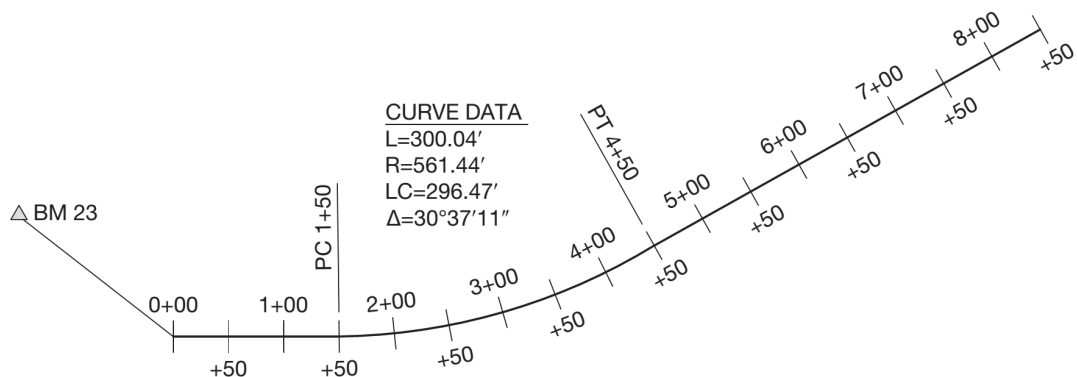


Figure 11-1. A simple depiction of the centerline layout of a route. Profile leveling measurements are taken at the station points indicated along the centerline of the route.

The instrument is set up in a position from which several shots along the centerline can be taken. The rod is then placed on a point with a known elevation, such as the bench mark (BM). A reading is now taken on the rod at the point of known elevation, identified as the backsight (BS). The **BS** is the rod or target location in surveying from which a reference measurement is made. The BS reading is added to the elevation of the known point to give the height of the instrument (HI). The rod is then placed at intervals along the centerline of the route. Each interval is a point with an unknown elevation to be measured, identified as the intermediate foresight (IFS). An **IFS** is a separate elevation taken in addition to the run of levels for information purposes. The location of IFS readings is determined by the topography.

Stationing normally locates station (STA) points every 50' (15 m) or 100' (30 m) from the beginning of the project. 0+00 designates the beginning of the project. A **full station** is 100' (30 m). For example, 10+00 is a full station 1,000' from the beginning. A **plus station** specifies a point between full stations. For example, 4+63.25 is a plus station that indicates a point 463.25' from the beginning. Plus stations are located at sudden elevation changes such as bank and stream edges, road edges and centerlines, and the tops and bottoms of ditches. When using the metric system, station numbers are specified as the distance from the point of beginning, without using the plus system.

When IFS readings can no longer be taken from the instrument setup, a new instrument station is needed. The rod is placed on a turning point (TP), and a foresight (FS) reading is taken. A **TP** is a temporary BM such as a large rock, fire hydrant, concrete curb or foundation, wooden stake, or metal spike, on which the rod is rested and used as a pivot for the rod. The **FS** is the rod or target location in surveying to which an elevation and/or location reading is taken. The instrument is then moved ahead to a location from which additional IFS readings can be made.

To check the profile leveling survey, it is necessary to close on another BM. The difference between the totals of the BS readings and the FS readings is the elevation difference between the beginning and end points. For example, if the totals of the BS readings are +14.65 and the totals of the FS readings are -6.79, the difference is +7.86 ($+14.65 - 6.79 = +7.86$). This value should be the HI reading when the rod is placed on the final BM. Field notes for profile leveling are similar to those for differential leveling, with the addition of station values and IFS readings. Figure 11-2 shows an example of profile leveling field notes.

Plotting a Leveling Profile

Profile field notes are plotted on a grid with a series of horizontal and vertical guidelines. The bottom line of the profile represents the horizontal distance on the route of the survey and is often labeled with the station point values. As explained in more detail later in this chapter, the vertical aspect of the profile is an exaggerated scale

Profile Leveling Computation					
Proposed Pine Ridge Bike Path					
STA	BS(+)	HI	FS(-)	IFS(-)	ELEV
BM 23	4.12				315.00
		319.12			
0+00				4.99	314.13
0+50				6.77	312.35
1+00				7.31	311.81
1+50				7.95	311.17
2+00				8.66	310.46
TP 1	3.01		8.95		310.17
		313.18			
2+50				3.37	309.81
3+00				4.58	308.60
3+50				5.35	307.83
4+00				5.71	307.47
4+50				6.48	306.70
5+00				5.92	307.26
5+50				5.70	307.48
TP 2	7.80		5.54		307.68
		315.44			
6+00				7.53	307.91
6+50				6.70	308.74
7+00				5.92	309.52
7+50				5.19	310.25
8+00				4.42	311.02
8+50				3.97	311.47
	BS total = 14.93		FS total = 14.49		BM 315.00 -HI 315.44 0.44
Level check				FS 14.93 -BS 14.49 0.44	

Figure 11-2. Profile leveling field notes include the station value and elevation at each station.

labeled with elevation values. The elevations of each station are taken from the field notes and plotted on the profile. Figure 11-3 shows a leveling profile created from the field notes shown in Figure 11-2.

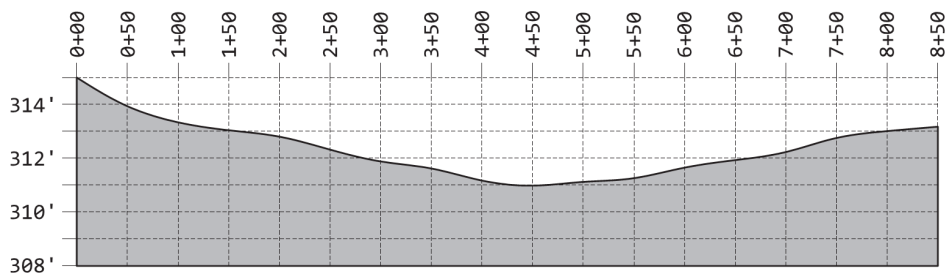


Figure 11-3. The leveling profile drawing created using the field notes shown in Figure 11-2.

Profiles are created for projects that consist of a single straight line; a series of connected straight lines, such as utility lines; or straight lines connected by curves, such as highways. The profile information is plotted in the same manner, but the plan drawing or map indicates the true appearance of the feature. This is illustrated by the plan and profile drawing, explained in the next section of this chapter.

Plan and Profile

A profile references a plan view and is drawn to show the elevation of plan view features. A profile may appear on the same sheet as the matching plan or may be drawn on a separate sheet depending on drawing, sheet, and project requirements. When the time comes to assemble documentation for a design that includes profiles, it is common for profile views to be accompanied by their corresponding plan views. A **plan and profile** is a type of drawing that combines the plan view of a project, or often a specific portion of a project, with the corresponding profile of the plan below. When applied to basic drafting theory, consider the plan to be the top view and the profile to be the front view presented as a section. The plan is most often placed above the profile. A plan and profile drawing is convenient to use because it allows both the plan and cross section of a specific area to appear on the same sheet.

Many civil engineering projects from roadways to underground utilities make use of plan and profile drawings. Figure 11–4 shows an example of a grading plan and profile used to show existing and proposed topography. **Grading** refers to the process of building a specific slope or level surface. Chapter 12 provides more information about grading. The profile view often occurs through the centerline of a road to illustrate gradient and curves. Figure 11–5 shows an example of a plan and profile used in the design of a sewer rehabilitation project. Notice in this example that the profile is drawn above the plan, which is less common than drawing the plan above the profile.

Profiles always correspond to plan views but are often not drawn in the plan and profile format. A plan may be drawn on one sheet and a profile shown on another. A cutting-plane line is usually used to associate the plan with the profile. A **cutting-plane line** is a line drawn on a plan view to show the location of a cross section cut. A cutting-plane line usually terminates with arrowheads or other symbols that point toward the cutting plane, indicating the line of sight when looking at the cross section. Cutting-plane lines often include information to help key the plan view to the cross section in a set of drawings. Figure 11–6a displays a portion of a site plan with a cutting-plane line. The letter in the top half of the cutting-plane line symbol is the identification for the section, and the information in the lower half of the symbol indicates the sheet on which the section is shown. The sheets in a set of drawings for a project are numbered sequentially. To find profile 1 in Figure 11–6a, go to sheet C4 of the drawing set. Figure 11–6b shows profile 1.

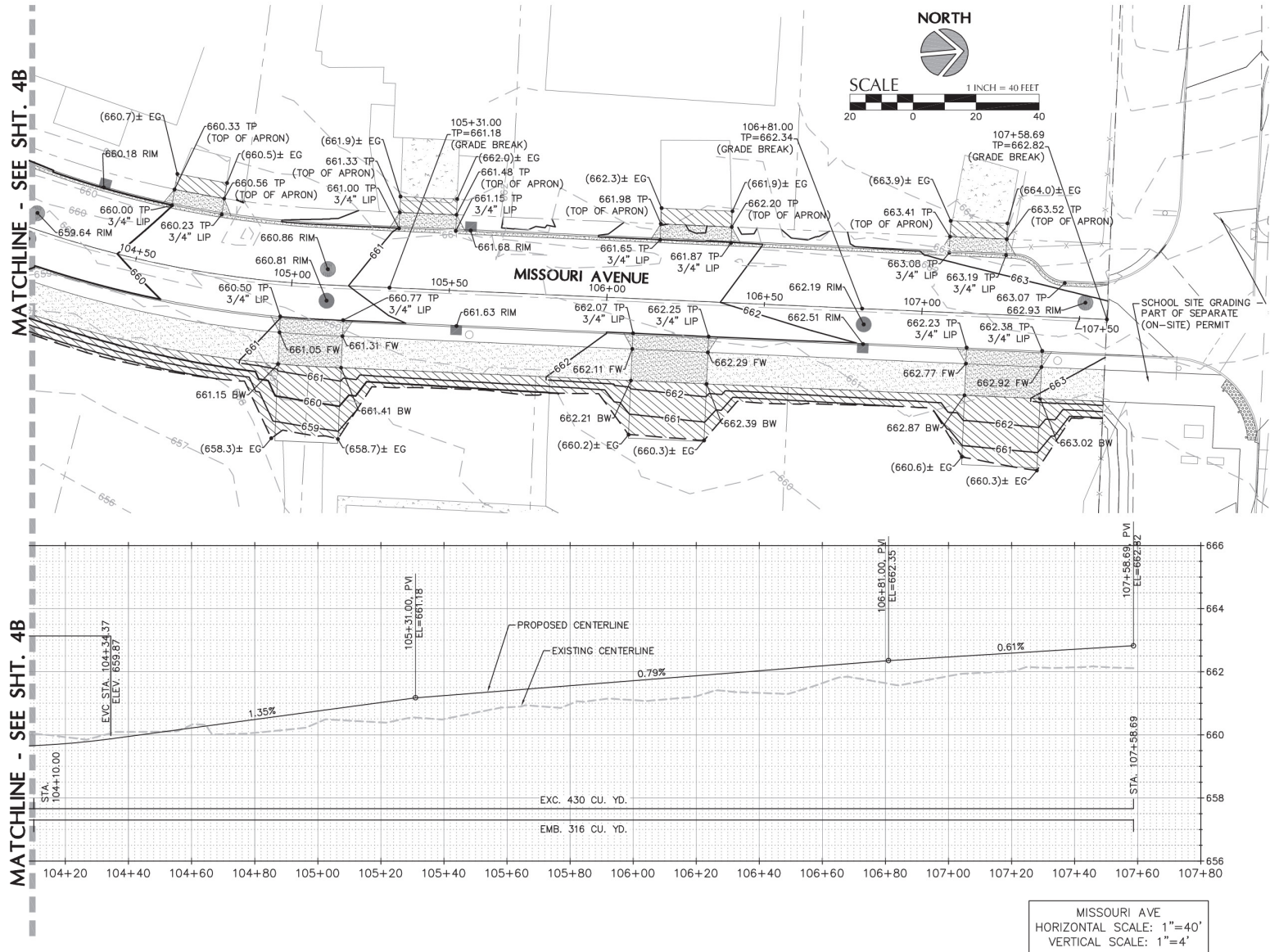


Figure 11-4. A grading plan and profile used to show existing and proposed topography.
(Courtesy of KPFF Consulting Engineers)

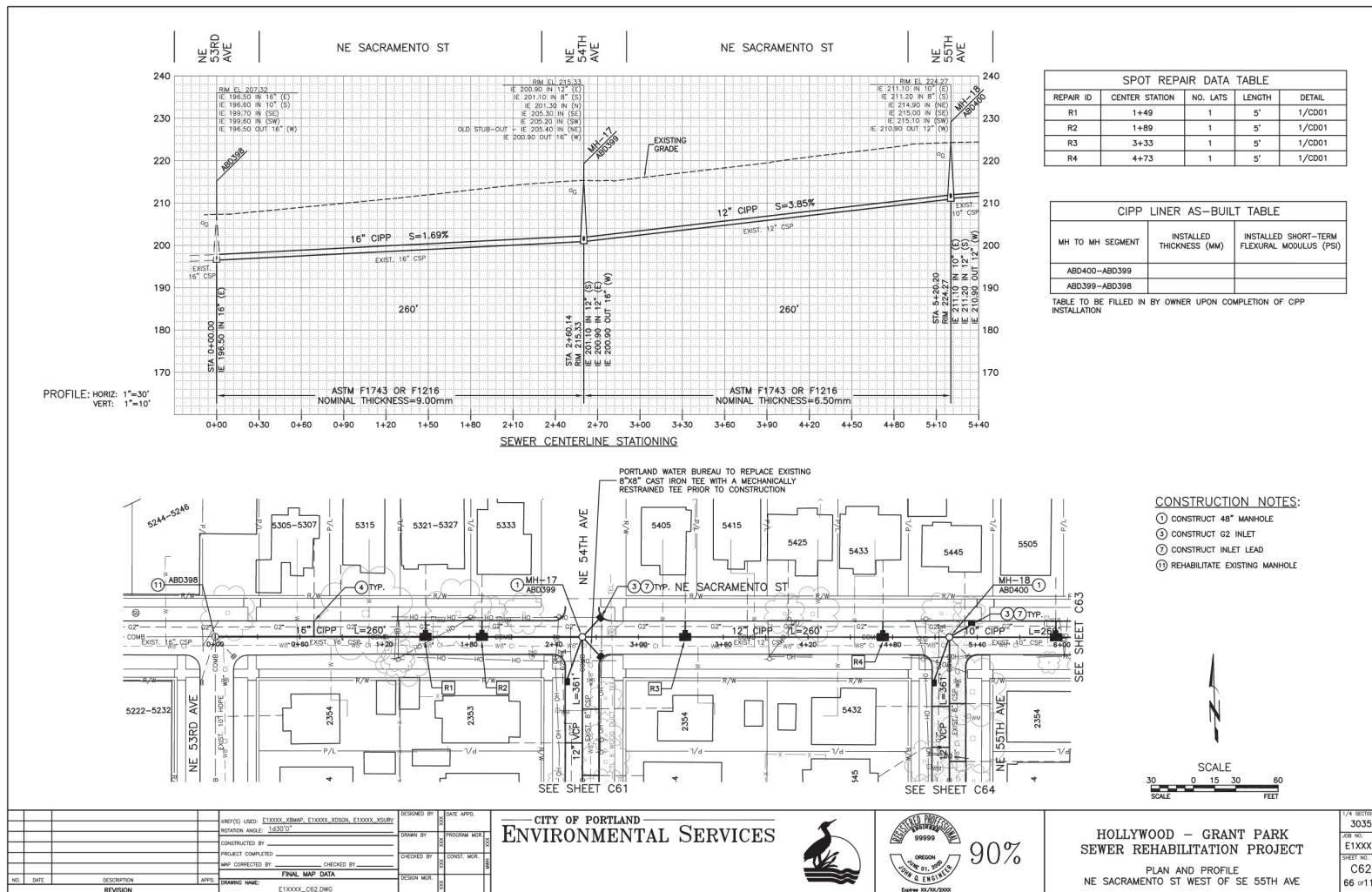


Figure 11-5. A sewer rehabilitation plan and profile used to document sewer line construction.
(© City of Portland, courtesy Bureau of Environmental Services)

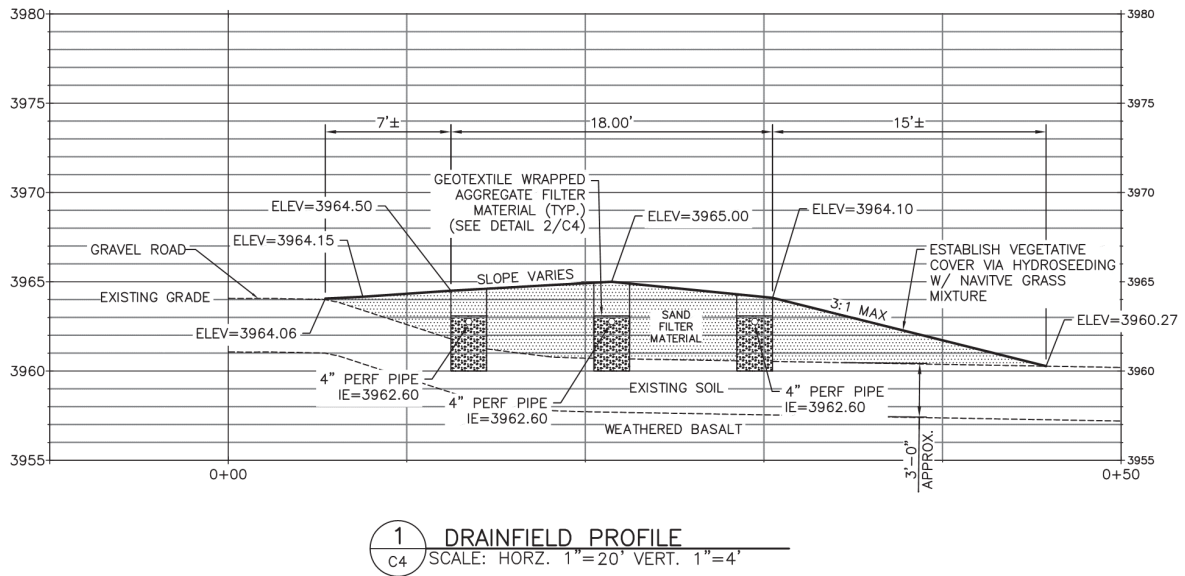
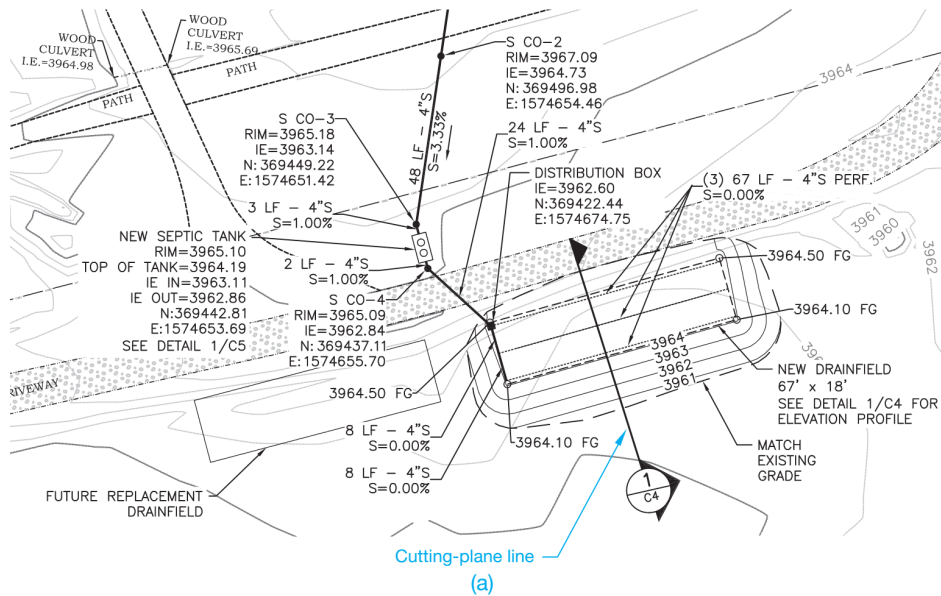


Figure 11-6. (a) Cutting-plane line symbols shown on a plan view of a proposed septic system construction project. Profile 1 is shown on sheet C4, and the view is to the right. (b) This is profile 1, cut on the plan view sheet and shown on sheet C4.
(Courtesy of KPFF Consulting Engineers)

Layout and Construction

A plan displays all pertinent information necessary for the horizontal layout of a project. A profile depicts the vertical aspect of a horizontal route, including the heights and depths of straight-line segments and vertical curves. The following information focuses on the procedure

for manually constructing a plan and profile using a general CADD system such as AutoCAD. This content provides useful information about profile layout and construction.

The drawing scale assigned to plan and profile views is an initial consideration in laying out a plan and profile. Plan view scale varies depending on the size of the geographical area, the amount of required detail, and the size of the sheet and drawing area on which the plan is drawn. Examples of common civil engineering plan drawing scales are $1'' = 10'$, $1'' = 20'$, $1'' = 50'$, $1'' = 100'$, and $1'' = 200'$. In contrast to a plan view, a profile usually has two drawing scales; a horizontal scale usually equal to the plan view scale, and an exaggerated vertical scale related to the elevation difference in the profile view.

A profile on a plan and profile drawing is often projected from the plan and therefore typically shares the same horizontal scale. The vertical scale of a profile on a plan and profile drawing is almost always exaggerated. Exaggerating the vertical profile scale helps to clearly show changes in elevation. For example, a sanitary sewer line may only rise $10''$ vertically over a $100'$ horizontal run. Exaggerating the vertical profile scale is necessary to show this small amount of slope. The amount of exaggeration depends on the relief of the map, the scale of the map, and the purpose of the profile. Examples of vertical scale exaggeration ratios are 2:1, 3:1, 5:1, and 10:1. For example, if the plan view scale is $1'' = 50'$, the vertical scale of the profile will be $1'' = 5'$ using a 10:1 ratio.

Figure 11-7 shows the plan view layout of a small section of sanitary sewer (SS) line and two manholes. The annotations at each manhole provide the information necessary to construct the profile. The first step to lay out the profile is to project the features, such as the endpoints of the sewer line and the center points of the sanitary sewer manholes (SSMH) into the profile. Then, create vertical grid lines based on the distance required between station points. This example uses 50' stations. The endpoints of the sewer line in this example coincide with station points (see Figure 11-8).

The next step in constructing the profile is to use the elevation data given to determine the lowest and highest elevations and then establish the bottom outline of the profile. Construct horizontal lines at appropriate reference elevation values in the profile view. The lowest pipe elevation is $649.00'$ at SSMH-4, so $648'$ is used as the lowest elevation in the profile. Allow some space between the highest and lowest elevations of the profile. This example uses a $1'' = 4'$ vertical profile scale, which is exaggerated from the $1'' = 20'$ plan

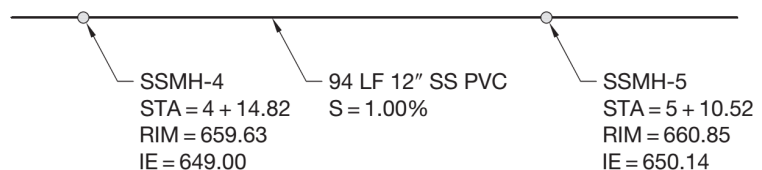


Figure 11-7. Begin the plan and profile drawing with the plan layout of a small section of sanitary sewer line and two manholes.

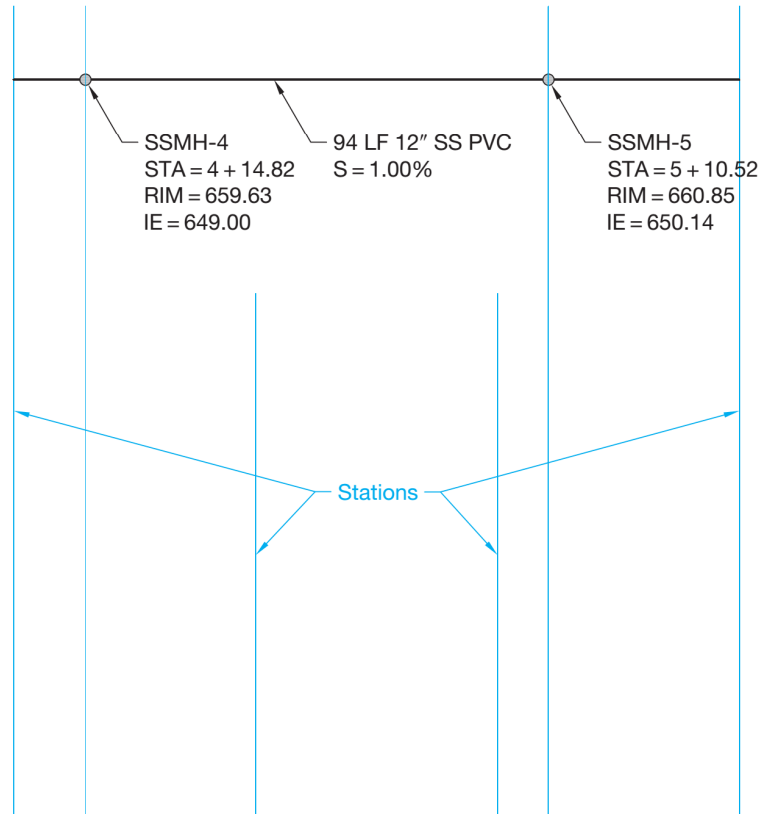


Figure 11-8. Project end points of the sewer line, manhole center points, and vertical grid lines based on the distance between station points into the profile.

scale using a 5:1 ratio. Offset 20' horizontal grid lines to represent 4' elevation intervals and add elevation text labels for reference (see Figure 11-9).

Now, in the profile, locate all elevations required at manholes, such as the elevation at the rim of the manholes (RIM) and invert elevation (IE). As explained in more detail later in this chapter, the IE is the bottom inside of the pipe. Remember when locating elevation points that the vertical profile scale is exaggerated. For example, the IE at SSMH-4 is 649.00'. This is 1' above the 648' grid. To properly locate this point, multiply 1 by 5. The result, 5', is the distance above the 648' grid to locate the IE. Construct the elevations to intersect the appropriate vertical line projected from the plan. For illustration purposes, only the manhole rim and invert elevations needed to construct the profile are shown to the left of the grid line elevations in Figure 11-10. Dots within the profile indicate where these elevations apply.

The next step is to draw lines representing features such as the manhole rims and the sewer line (see Figure 11-11). Determine whether the grade is natural ground or a flat surface, such as a street or sidewalk. The angle at which these lines extend past the

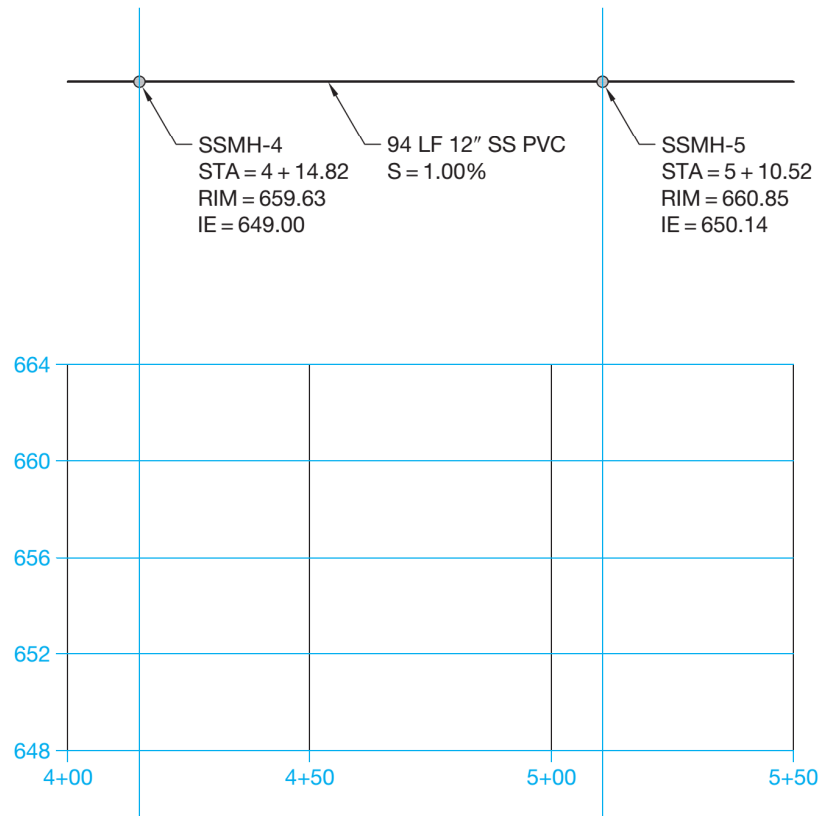


Figure 11-9. Establish the bottom outline of the profile and construct horizontal lines at appropriate reference elevation values in the profile view.

manholes to the edges of the profile are determined by the elevations of features not shown on this drawing. Apply symbols and labels as required. Figure 11-12 shows the completed plan and profile drawing.

Note: In the previous example, the plan scale is $1'' = 20'$, and the vertical profile scale is $1'' = 4'$, a ratio of 5:1. This means that the vertical profile measurements on your drawing should be five times their actual value. For example, the distance between the 648' and 652' grid lines (4') actually measures 20'.

Reading Plans and Profiles

Plan and profile drawings typically include many different symbols, terms, and abbreviations. The purpose of a drawing dictates the required content. The appearance and use of symbols, terms, and abbreviations are based on established standards, and project and drawing requirements. Refer to the previous figures in this chapter as you read the following information about specific plan and profile

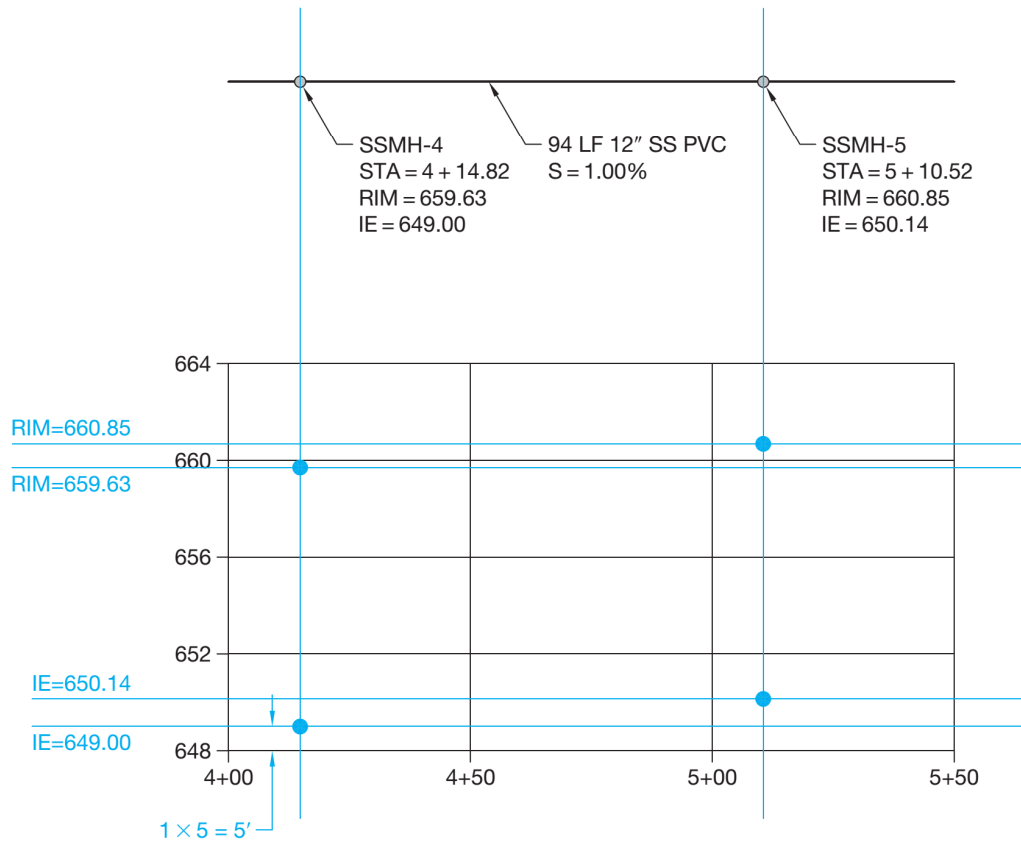


Figure 11-10. In the profile, locate all elevations required at manholes, such as rims of the manholes (RIM) and invert elevations of the pipe (IE).

content. The basic plan and profile example in Figure 11-12 shows a profile divided every 50' by vertical grid lines and every 4' by horizontal grid lines. At least one additional contour interval above and below the extreme points of the profiles are usually given. The elevations are labeled along one or both sides, and the scales are written by the profile. The vertical scale is sometimes written vertically near the elevation values.

At intervals along the plan view, sanitary sewer manholes (SSMH) are located along the route at a given station (STA) point value. The manhole symbol and station point value are shown as they appear in both plan and profile. Manholes are often abbreviated MH and are usually assigned a reference number. The Figure 11-12 sewer layout establishes elevations at the rims of the manholes. The rim elevations typically correspond with the finished grade along the route. **Grade (GR or GRD)** refers to an established elevation such as site or road grade. Grade may be given with the manhole number and station value on the profile and sometimes the plan. A sectioning symbol or shading is sometimes used to indicate the ground that is cross sectioned.

Invert elevation (IE) represents the bottom inside of a pipe. The IE value is established in the design layout of the pipeline and

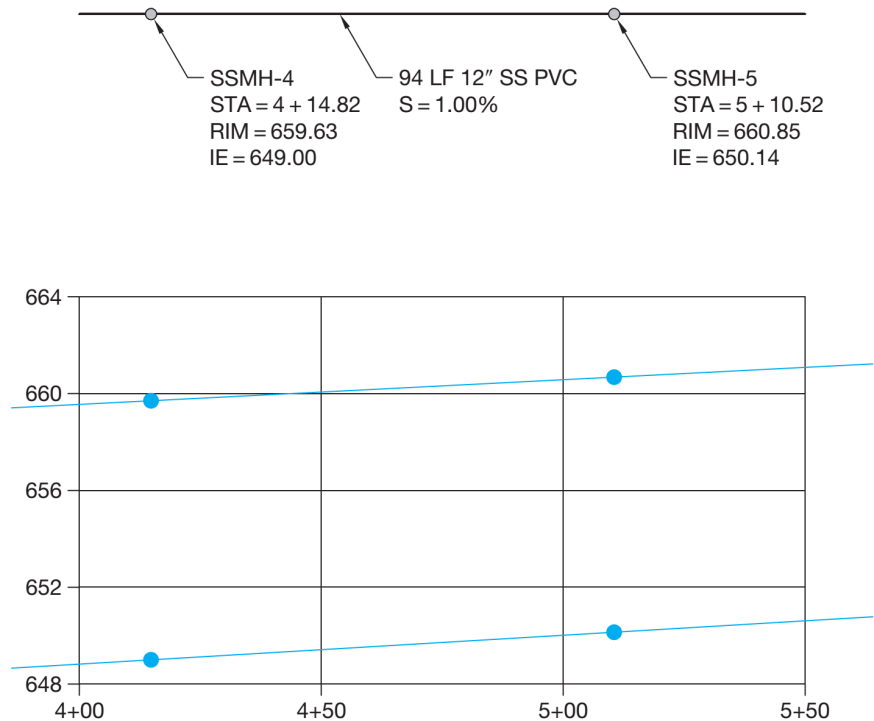


Figure 11-11. Draw lines representing features such as the manhole rims and the sewer line.

is important in the surveying, excavating, and construction aspects of the job. IE is usually found on the profile and sometimes the plan. Characteristics of the pipe including the distance between station points and the amount of slope are often indicated in the plan and profile. The pipe shown in Figure 11-12 is identified with the specific note 94 LF 12" SS PVC S=1.00%. In this example, 94 LF refers to the linear feet (LF) of pipe between the two manholes. 12" SS PVC denotes a 12" diameter sanitary sewer (SS) plastic polyvinyl chloride (PVC) pipe. S=1.00% denotes that the pipe has a 1.00 percent slope. **Percent slope (S)**, or **percent grade**, equals $(\text{vertical rise} \div \text{horizontal run}) \times 100$. A 1% grade rises 1' vertically for every 100' of horizontal distance. Therefore, a 100% grade is a 45° angle. In some cases, the slope is given as a vertical rise in feet to horizontal run per foot. The arrow in the pipe shown in Figure 11-12 indicates the direction of flow.

Not all profiles in a plan and profile drawing are located directly under the plan, although this is the ideal situation. Some pipelines or sewers may take several turns through a new subdivision, for example, and as a result, the plan itself may not be a linear shape. In this case, the plan may be located to the left of the drawing, with the profile on the right. The profile always appears as a straight line or flat plane, but the plan view may show several turns in the route. The profile is constructed in the same manner as previously described, but you will not be able to project points from one view to the next.

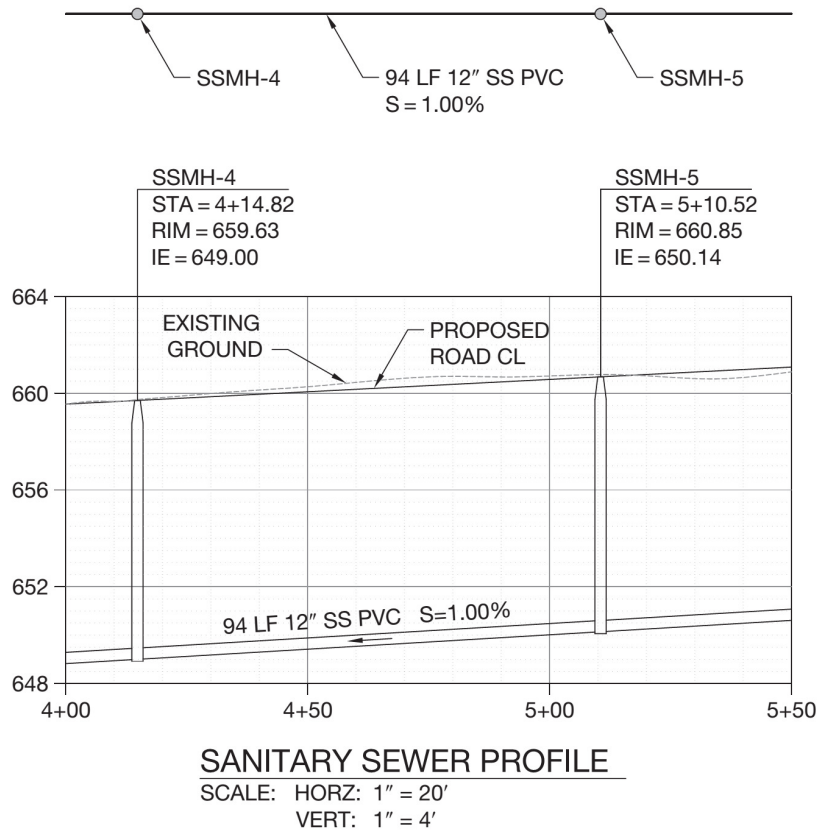


Figure 11-12. The completed plan and profile drawing of a section of sanitary sewer line.

Vertical Curves

The plan view of a route shows all necessary horizontal control including bearings, distances, radii, and angles. All necessary vertical control, or alignment, is shown on the profile. **Vertical alignment** defines the vertical form, or change in elevation, of a route on a vertical plane, or profile. For example, vertical alignment specifies the straight inclines and vertical curves in a road as displayed on a profile. A **vertical curve** is a feature that is provided to change vertical alignment between different slopes.

A vertical curve in roadway design is the shape of the road or highway as it crests a hill or reaches the bottom of a valley (see Figure 11-13). A **sag curve** is a vertical curve that changes the vertical alignment of a road from downhill to level or downhill to uphill. A **crest curve**, also known as a **summit curve**, is a vertical curve that changes the vertical alignment of a road from uphill to level or uphill to downhill.

Curve Layout

Figure 11-14 shows the layout of a vertical curve in a profile view. The begin vertical curve (BVC) is labeled, as is the end vertical curve (EVC). The vertical curve occupies this entire distance in this example and



Figure 11-13. A photograph of a highway showing vertical curves used to change vertical alignment.
(Hoda Bogdan/Fotolia)

is labeled on the profile as a 200' vertical curve (VC). Unlike a simple horizontal curve which is measured as a radius, a vertical curve is measured as a horizontal distance. The point of intersection (PI), also known as the point of vertical intersection (PVI) on the profile is the intersection of the projected grade lines or grade slopes (g_1 and g_2). The elevation of the PI can be calculated using the elevations of the BVC, EVC, and grade slopes. Grades are given as percentages.

The vertical curve is tangent to two points, stations 4+00 and 6+00. A straight line connecting these two stations has an elevation

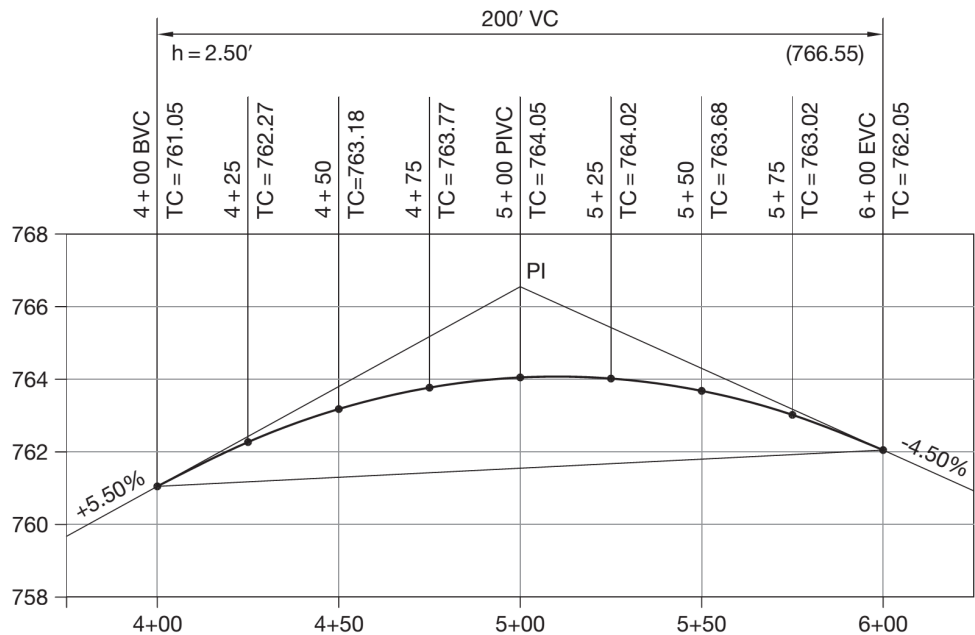


Figure 11-14. A vertical curve layout in a profile view.

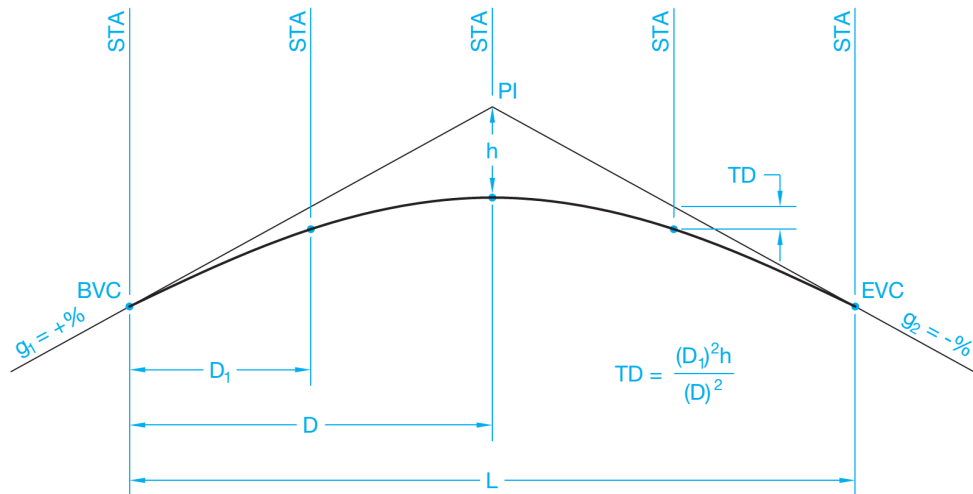


Figure 11-15. Components of the vertical curve formula.

of 761.55' directly below the PI, and the vertical distance between the PI and the straight line is 5.00'. The vertical curve will pass mid-way through this distance and have an elevation of 764.05'. The distances from the grade line to the curve at each station point can be calculated using the following formula:

$$\frac{(D_1)^2 h}{(D)^2} = TD$$

The tangent distance (TD) is the measurement from the grade line to the profile of the curve at a station point. Once you solve the formula for the TD, the TD can be subtracted from the elevation of the grade line to give you the elevation of the road profile at a specific station point.

Figure 11-15 identifies the components of the TD formula. The distance between the BVC and the PI is labeled D, and the distance from the BVC to the required station is D₁. The height of the midway point directly below the PI is termed h. It can be stated that the distances from the grade line to the road profile are proportional to the squares of the horizontal distances from the tangent points.

Figure 11-16 provides the calculations for all the points of the vertical curve shown in Figure 11-14. The **ordinate** is the tangent distance from the top of the curve to the grade tangent line at each horizontal station point. You can plot the points of the vertical curve at each station and then connect the points to create the curve. This line becomes the profile of the proposed road. Elevations of the road are often written vertically at each station point as shown in Figure 11-14.

Profiles with Civil CADD

Designing a profile adds a third dimension to the two-dimensional (2-D) horizontal alignment described in Chapter 10, by creating a three-dimensional (3-D) path that serves as the baseline of the road.

Station	Tangent Elevation	Ordinate	Curve Elevation (TC)
4+00	761.05	0	761.05
4+25	762.43	0.16	762.27
4+50	763.81	0.63	763.18
4+75	765.18	1.41	763.18
5+00	766.55	2.50	764.05
5+25	765.43	1.41	764.02
5+50	764.31	0.63	763.68
5+75	763.18	0.16	763.02
6+00	762.05	0	762.05

Figure 11-16. Points of the vertical curve shown in Figure 11-14.

However, in order to understand what the design of the profile must be, the designer must first illustrate the profile of the existing ground elevations along the alignment. CADD programs typically offer tools and functions that automate or optimize the tasks of establishing the existing ground profile and designing the finished ground profile.

Establishing the Existing Ground Profile

A roadway project completed within a CADD program will most likely contain a digital representation of the existing ground elevations, often referred to as a DTM, TIN, or terrain surface. Through a process called sampling, the CADD software reads the surface elevations along the alignment and generates a list of station and elevation pairs. In the case of AutoCAD Civil 3D, for example, the software captures and stores the station and elevation of every point at which the alignment crosses a triangle edge or TIN line in the surface. The profile itself is represented by plotting these stations and elevations on a grid. This whole process is highly automated and generally consists of selecting the alignment, the surface, and a location in the drawing area for the profile grid to be placed. Settings control a variety of elements such as the annotation that is shown on the profile grid and the vertical exaggeration of the profile view.

In Figure 11-17, the alignment in the top of the view has been sampled along a surface to create the profile in the bottom of the view. The circles indicate locations where the alignment crosses a triangle edge. Notice how the circles correspond to the points that are plotted to create the profile.

Creating a Design Profile

Once an existing ground profile is established, the designer can then move on to creating the new profile, also known as the design profile or finished ground profile. This is a very different process from creating the existing ground profile, which is an automated process done by the computer. The design profile is drawn by the designer

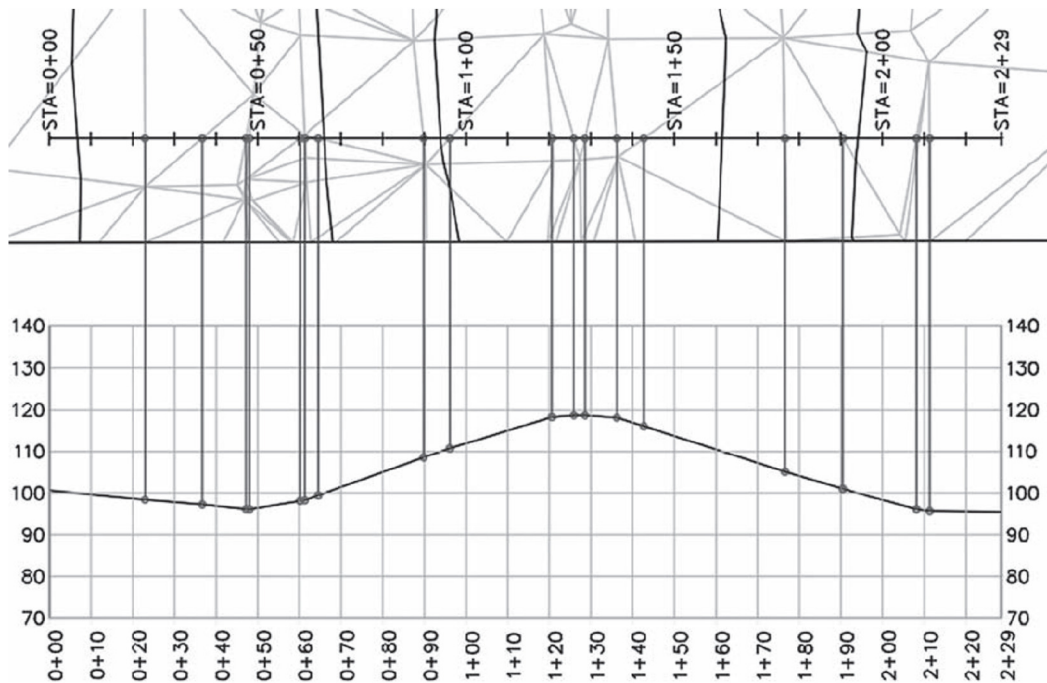


Figure 11-17. Sampling an alignment along a surface to create a profile.
(Courtesy of Eric Chappell and Autodesk, Inc.)

using CADD program tools to optimize the process. For example, AutoCAD Civil 3D profile creation tools provide built-in geometric controls, which ensure that the vertical curves remain tangent to the straight-line segments of the profile. As the designer takes advantage of these automation and optimization tools, he or she will draw the profile attempting to stay as close to existing ground as possible, to minimize cut and fill, while adhering to standards dictating slope, curve length, and other properties that affect the profile. Figure 11-18 displays picking points in AutoCAD Civil 3D to locate PVIs. The software automatically creates vertical curves and ensures that they are tangent.

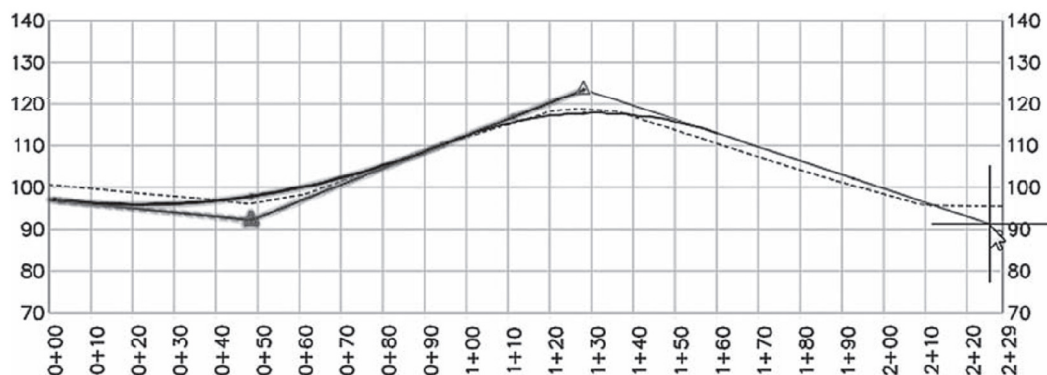


Figure 11-18. Picking points in AutoCAD Civil 3D to locate PVIs.
(Courtesy of Eric Chappell and Autodesk, Inc.)

Editing a Design Profile

After first creating a design profile, the designer will typically edit the profile to improve the design. As with alignments, most CADD programs offer graphic, command-based, and numerical editing. In the case of AutoCAD Civil 3D, specialized grips allow editing of the profile with built-in constraints. Figure 11–19 shows graphically modifying the slope of one tangent while maintaining the other using a specialized grip.

Using a command-based editing approach, a designer might add or remove PVI or vertical curves, or change the elevations of multiple PVIs at once. Figure 11–20 displays an AutoCAD Civil 3D command that can change the elevations of multiple PVIs at once. Using a numerical editing approach, a designer can enter values such as slopes, elevations, and curve lengths. This can be done one value at a time or all at once using a tabular interface. Figure 11–21 shows using the tabular Panorama interface of AutoCAD Civil 3D to change the length of a vertical curve.

Labeling Profiles

CADD programs provide tools that automate the labeling of existing ground and design profiles. Existing ground profiles are not typically labeled. Design profiles often include annotation showing the grades of tangents and the curve data that defines vertical curves. Design profile labels are often dynamically linked to the profile enabling them to update automatically as changes are made. Figure 11–22 displays labels on a profile view that define the tangent slopes and the geometry of the curves.

Showing Pipes in Profile View

It is common to show underground piping in profile view, as it is an effective way to illustrate the slopes and elevations that are crucial in determining how a piping system performs or how well it avoids obstacles and conflicts. CADD programs include tools that automate the graphical

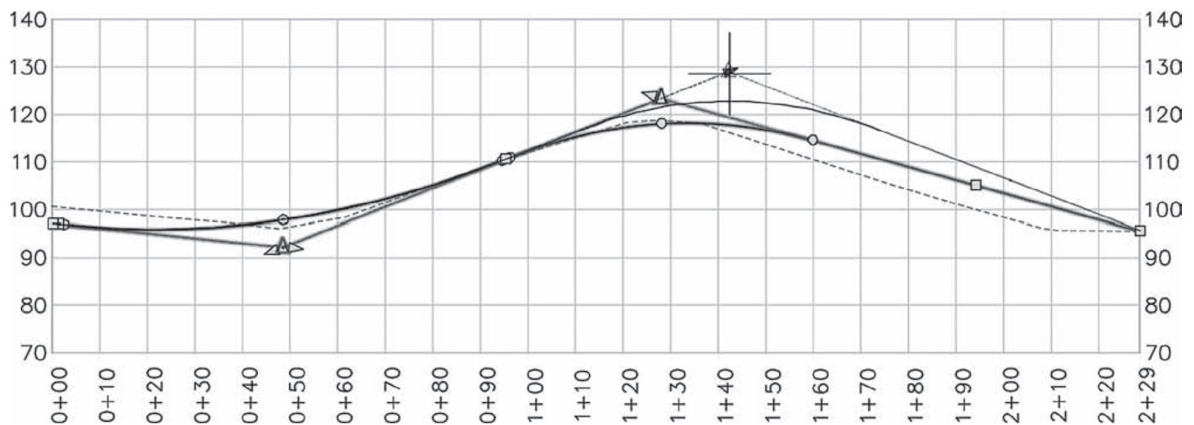


Figure 11–19. Using a specialized grip to graphically change the slope of one tangent while maintaining the other.

(Courtesy of Eric Chappell and Autodesk, Inc.)

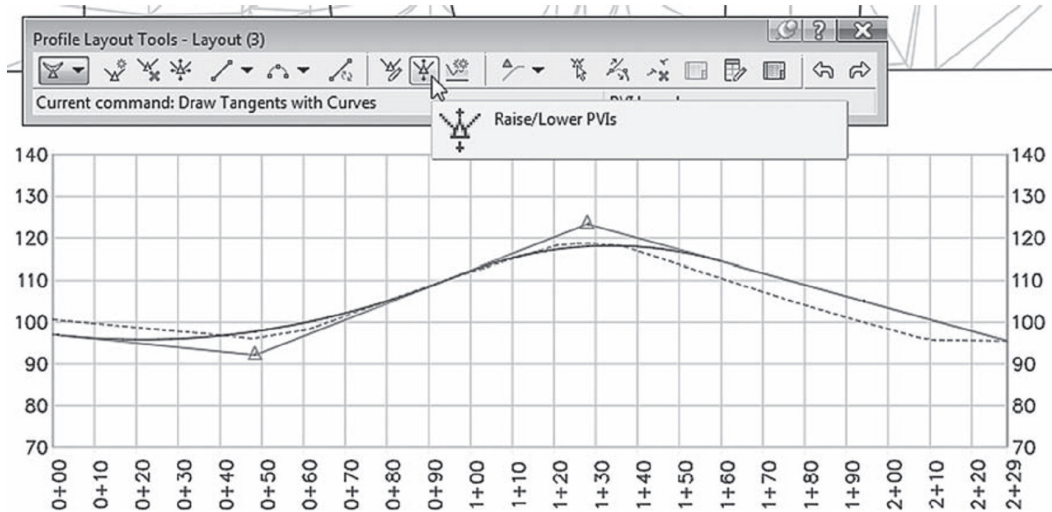


Figure 11-20. An AutoCAD Civil 3D command that can change the elevations of multiple PVIs at once.

(Courtesy of Eric Chappell and Autodesk, Inc.)

representation of piping systems in the profile view and tools for labeling key information about the piping systems (see Figure 11–23).

Plan and Profile Sheets

CADD programs typically include a series of functions that automate the process of creating plan and profile sheets. In the case of AutoCAD Civil 3D, this tool set is known as the Plan Production tool set. Perhaps the most beneficial function of Plan Production is its ability to break down a long alignment into individual viewable areas using objects called View Frames. Since a long linear design like a road or pipeline cannot typically be viewed on one sheet, a series of sheets

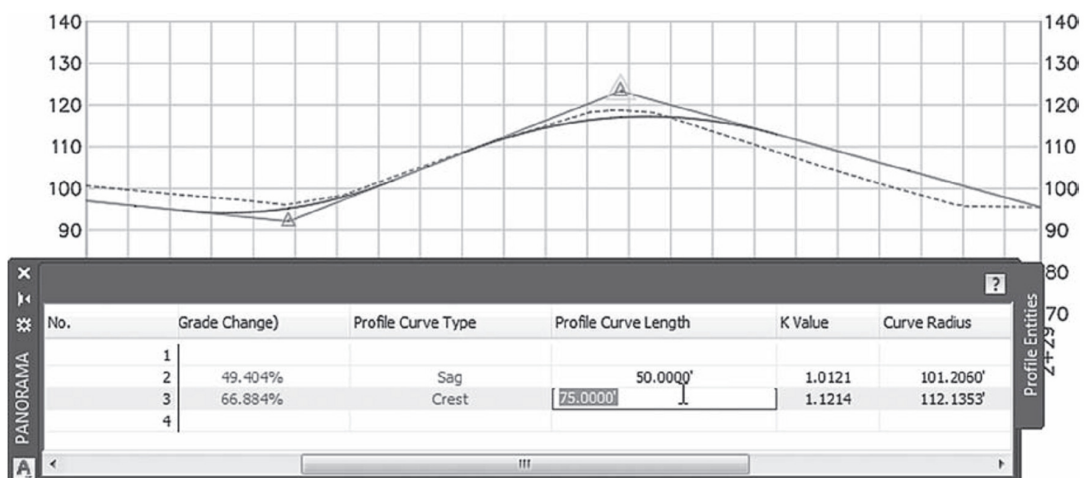


Figure 11-21. Using the tabular Panorama interface of AutoCAD Civil 3D to change the length of a vertical curve.

(Courtesy of Eric Chappell and Autodesk, Inc.)

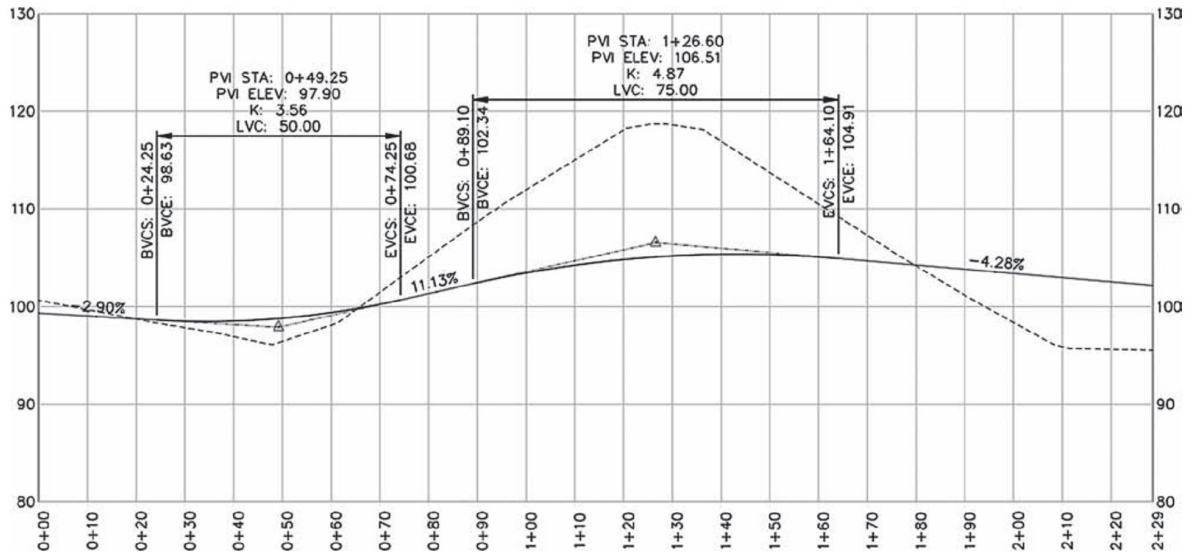


Figure 11-22. Labels on a profile view used to define the tangent slopes and the geometry of the curves. (Courtesy of Eric Chappell and Autodesk, Inc.)

must be used with match lines employed to show where the sheets match one to another. Plan Production automatically lays out these view frames based on the desired drawing scale, sheet size, and many other parameters. The view frames are then used to create individual plan and profile views that are automatically arranged into sheets, ready to be plotted. Figure 11-24 shows a plan and profile sheet generated using civil CADD software.

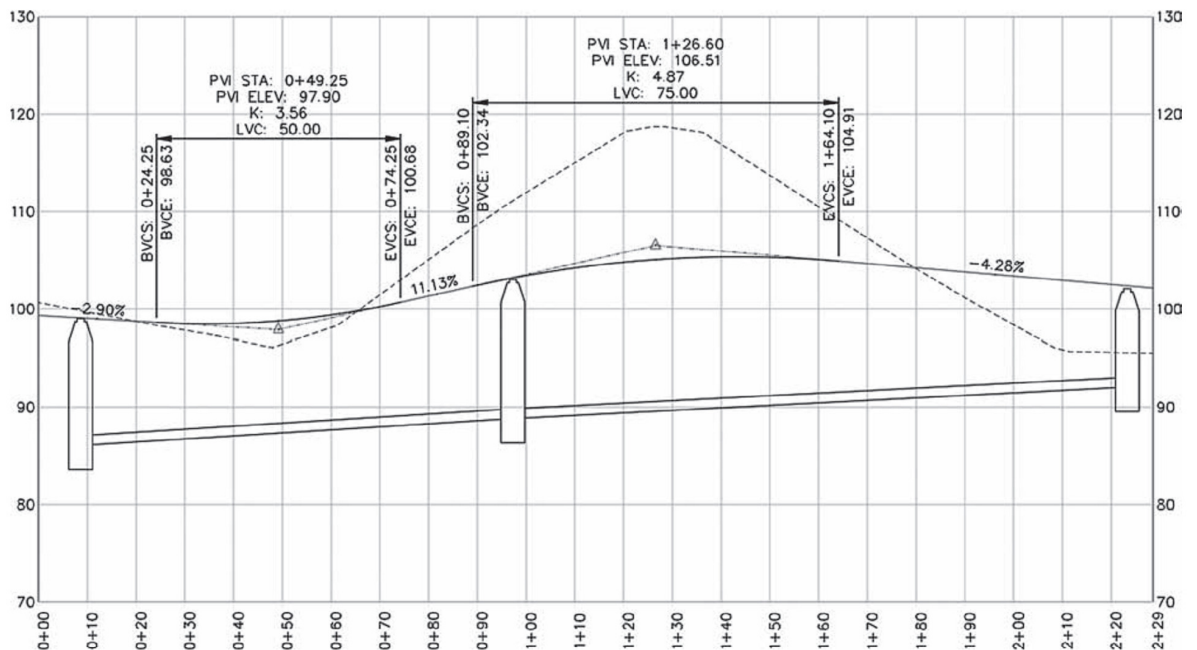


Figure 11-23. Lines added to a profile view to represent manholes and underground pipes. (Courtesy of Eric Chappell and Autodesk, Inc.)

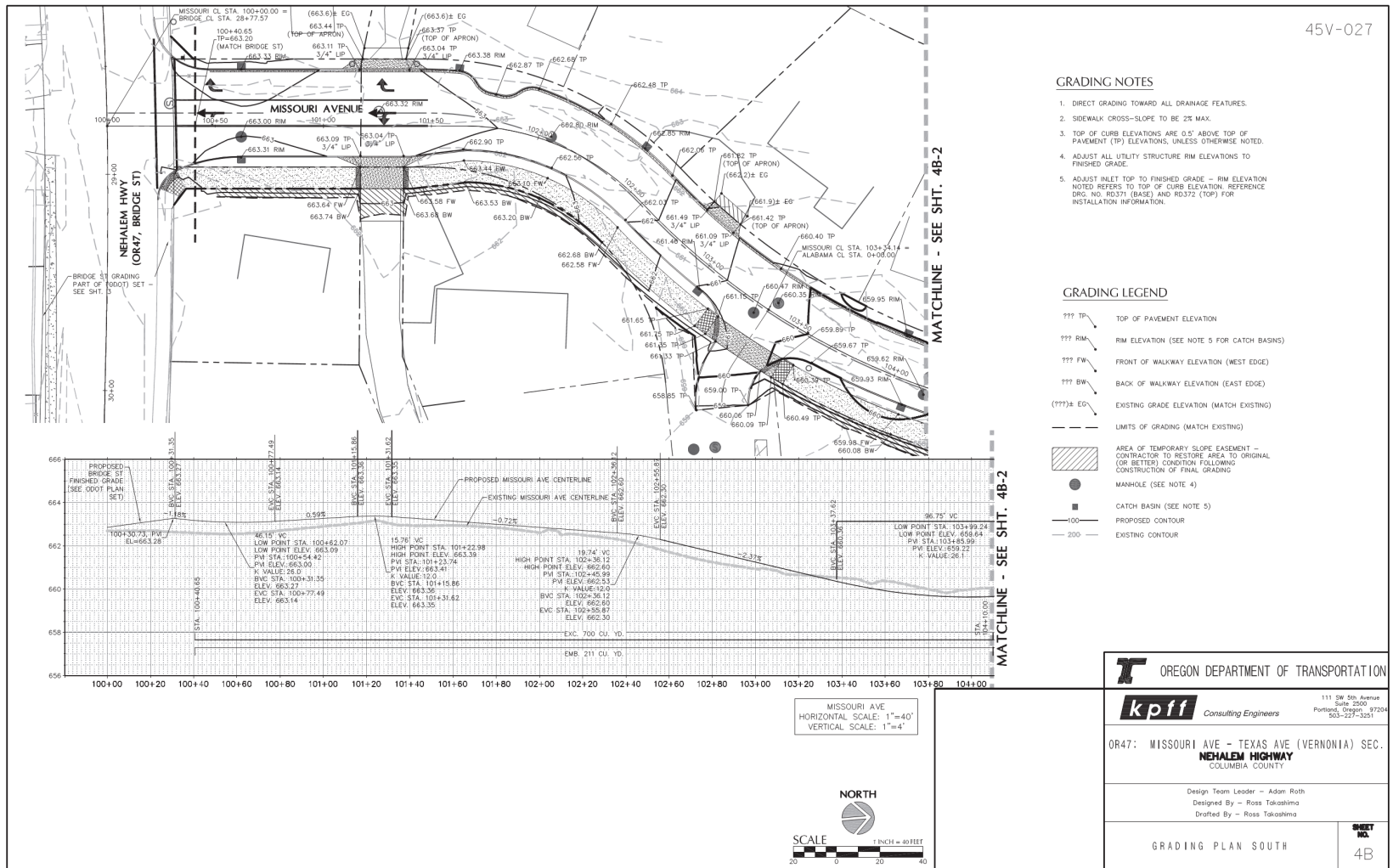


Figure 11-24. A grading plan and profile used to show existing and proposed topography.
(Courtesy of KPFF Consulting Engineers)

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Answer the following questions.

- 11-1** What is a profile?
- 11-2** What three types of drawing are usually required to provide all of the design information needed to lay out a civil engineering project?
- 11-3** Why is a profile necessary for road construction?
- 11-4** Define profile leveling.
- 11-5** How is the location of an IFS determined?
- 11-6** A point established every 100' in a route survey is called a _____.
- 11-7** Write the following values in the proper station format.
- 300' _____
- 567' _____
- 298.43' _____
- 11-8** Define plan and profile.
- 11-9** Define grading.

- 11-10** What scales are common for a plan drawing?
- 11-11** Why is the vertical scale of a profile drawing exaggerated?
- 11-12** What type of feature would require a profile leveling of connected straight lines and curves?
- 11-13** What is invert elevation?
- 11-14** What information is found next to a manhole symbol on a plan and profile?
- 11-15** What type of information does a vertical curve show?

Part 2

Study the portion of the storm drain (SD) profile shown in Figure R11-2 to answer the following questions. The entire profile sheet is also available for download and viewing. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Chapter 11 Profile.pdf.

- 11-16** The profile has a _____ horizontal scale and a _____ vertical scale.
- 11-17** The vertical scale is exaggerated using a _____ ratio.
- 11-18** The highest point specified on the profile is at station _____ with an elevation of _____.
- 11-19** The percent slope of the pipe between SDMH-6 and SDMH-5 is _____%.
- 11-20** The steepest slope indicated on the profile is _____%.
- 11-21** The proposed finished grade is the centerline of _____.

- 11-22** The elevation at the rim of storm drain manhole number five is _____.
- 11-23** The elevation at the rim of SDMH-6 is _____ higher than the elevation at the rim of SDMH-4, and _____ higher than the elevation at the rim of SDMH-5.
- 11-24** The dashed line along the route denotes the _____.
- 11-25** There is approximately _____ linear feet of _____ diameter storm drain pipe between SDMH-6 and SDMH-4.

Part 3

Study the portion of the street and storm drain plan and profile shown in Figure R11-2 to answer the following questions. The entire plan and profile sheet is also available for download and viewing. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Chapter 11 Plan and Profile.pdf.

- 11-26** The proposed grade at the centerline of NW Heckman east of NW 185th Avenue between EVCS 15+22.00 and BVCS 16+97.60 is _____%.
- 11-27** The shortest vertical curve on the drawing is _____ long with a point of intersection elevation of _____.
- 11-28** The longest vertical curve on the drawing is _____ long with a point of intersection elevation of _____.
- 11-29** The curve beginning at 14+80.00 is an example of a _____ curve and the curve beginning at 16+97.60 is an example of a _____ curve.
- 11-30** The sanitary sewer pipe is specified to have an _____ diameter, and the storm drain pipe is specified to have a _____ diameter.
- 11-31** The existing grade is above or below the proposed finished grade between the two vertical curves? _____
- 11-32** The elevation at the intersection of NW Heckman Lane and NW 185th Avenue is _____.

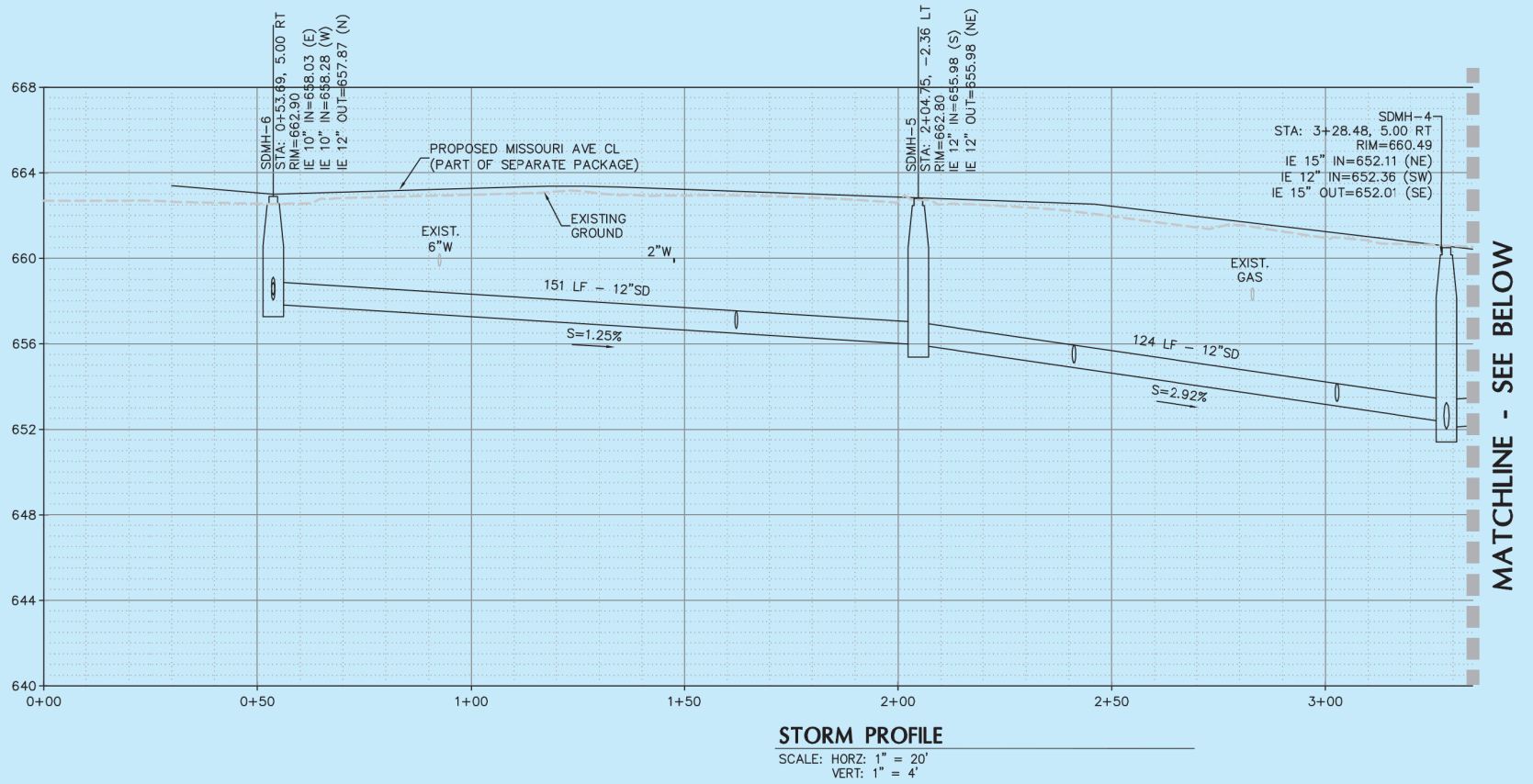


Figure R11-1.
 (Courtesy of KPFF Consulting Engineers)

11-33 The maximum slope for a storm drain line shown is _____.

11-34 At storm drain manhole C-3, the invert out elevation is _____ for a _____ diameter pipe.

11-35 SDMH H-3 is _____ in diameter, has one 12" invert in pipe at elevation _____, one 15" invert in pipe at elevation _____, one _____" invert in pipe at elevation _____, and one _____" invert out pipe at elevation _____.

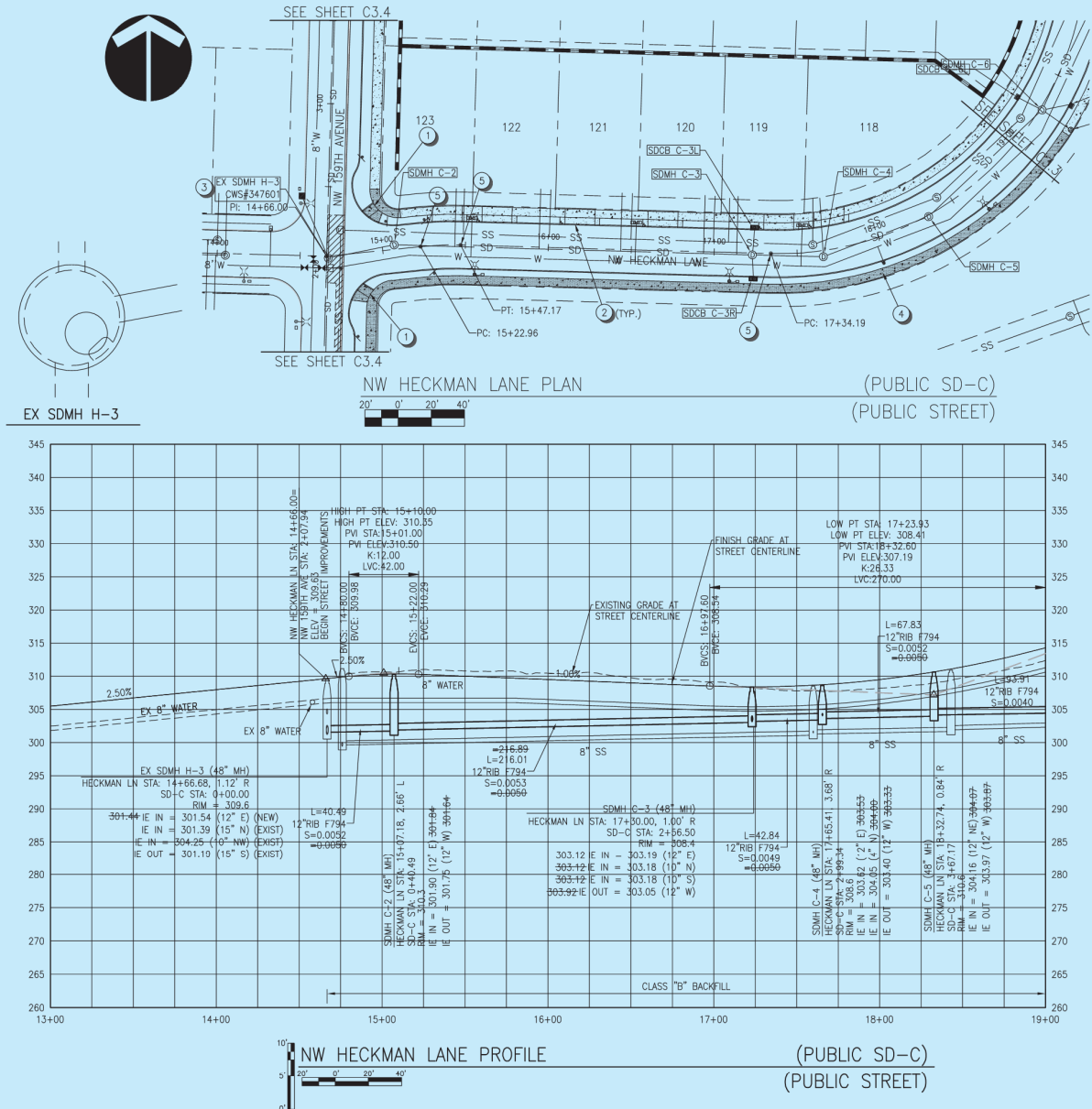


Figure R11-2.
(Courtesy of Otak, Inc.)
Profiles

PROBLEMS

Follow the specific instructions to complete each problem.

- P11-1** Use the finished drawing from Problem P8-5 to complete this problem. Construct a profile along line AB shown in Figure P11-1. Draw the profile using a $1'' = 100'$ horizontal scale and a $1'' = 30'$ vertical scale on an architectural C size sheet. Label vertical elevations and indicate horizontal and vertical scales. Use a proper sectioning symbol to indicate the Earth. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 11-1. dwg file to reference line AB on the plan.

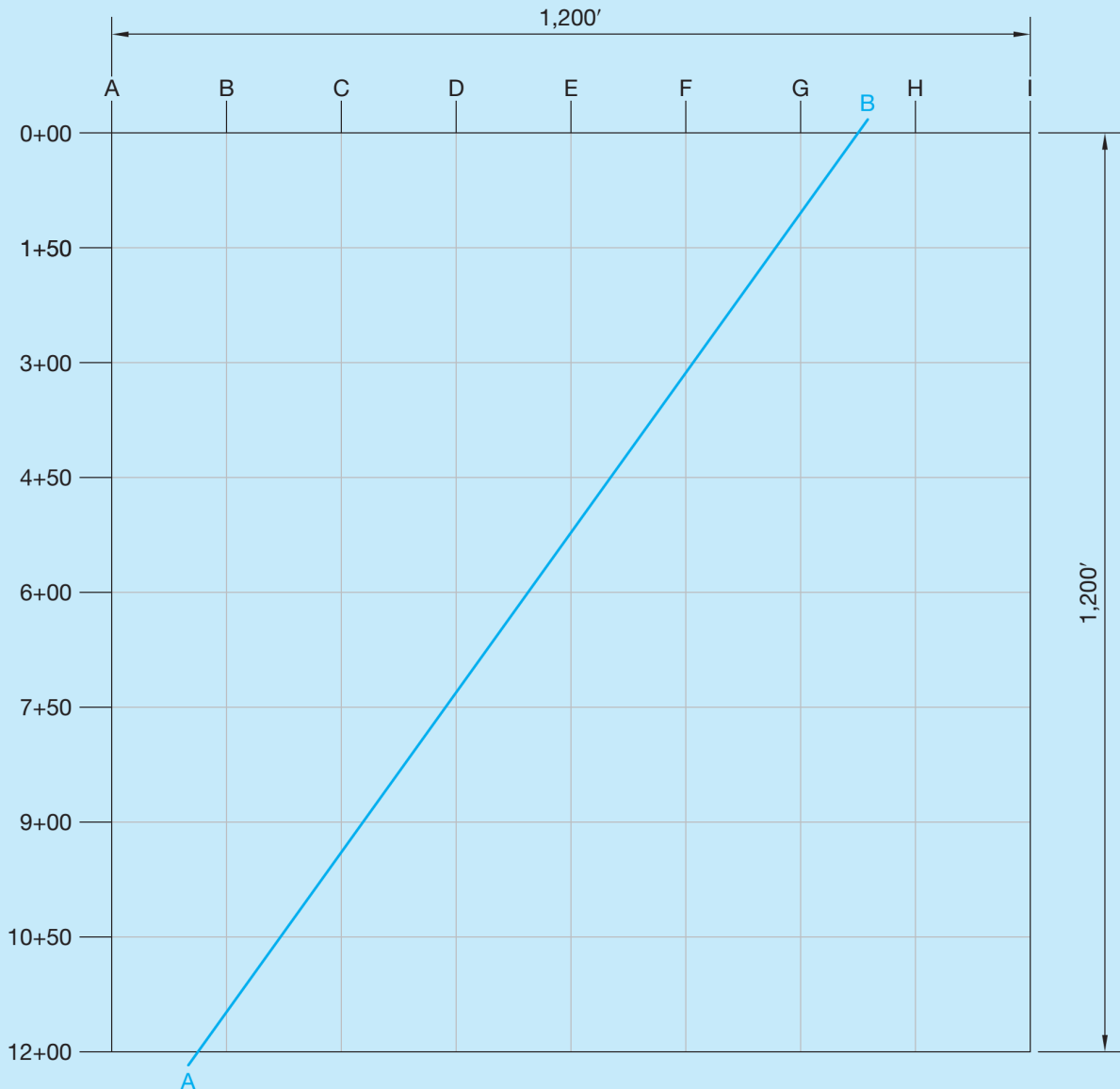
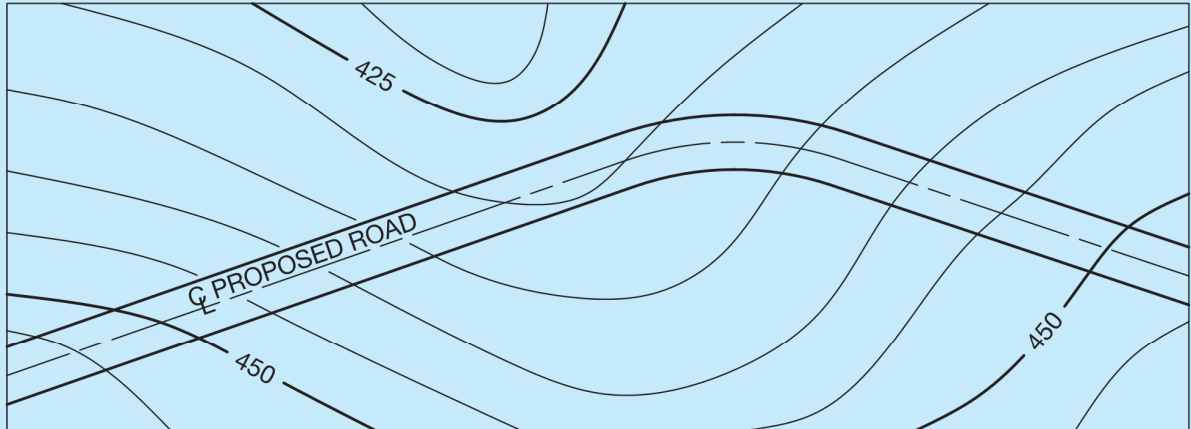
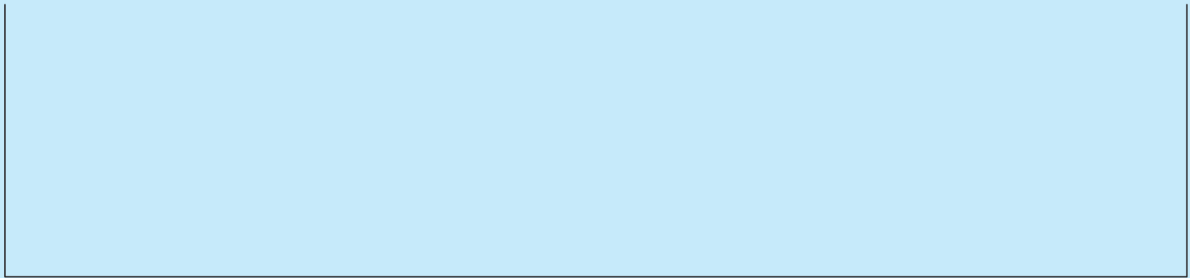


Figure P11-1.

- P11-2** Plot a profile of the 45' wide curved road shown in Figure P11-2. Draw the profile using a 1" = 100' horizontal scale and a 1" = 20' vertical scale on an ANSI C size sheet. Label vertical elevations and indicate horizontal and vertical scales. Use a proper sectioning symbol to indicate the Earth. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 11-2.dwg file to reference the plan.



Plan



Profile

Figure P11-2.

- P11-3** Survey stakes have been located along the centerline of a proposed street. A shot from the instrument to BM-1 has established an HI of 567.28'. Beginning at station 0+00, IFS shots have been taken at full stations for the length of the street, and their values are 0.8, 2.6, 3.1, 3.8, 4.5, 5.1, 6.4, 7.1, 7.5, 8.3, 7.7, 7.5, 7.0, 6.2, 5.4, 9.6, 8.1, 4.7, 3.9, and 3.5. Plot the profile from these stations. Plot the final drawing on an ANSI C size sheet. Select appropriate horizontal and vertical scales, and label the station and elevation values.

P11-4 The engineering sketch shown in Figure P11-4 is a plan view of a road and underground utilities. The sketch does not accurately reflect proper drafting and layout techniques, but the dimensions are accurate. Use the information given to draw a complete plan and profile on an architectural C size sheet. Select appropriate horizontal and vertical scales and draw and label all necessary information as described in this textbook. Label the distances and slope between manholes above the sewer pipe. Show water and gas lines in the plan view only.

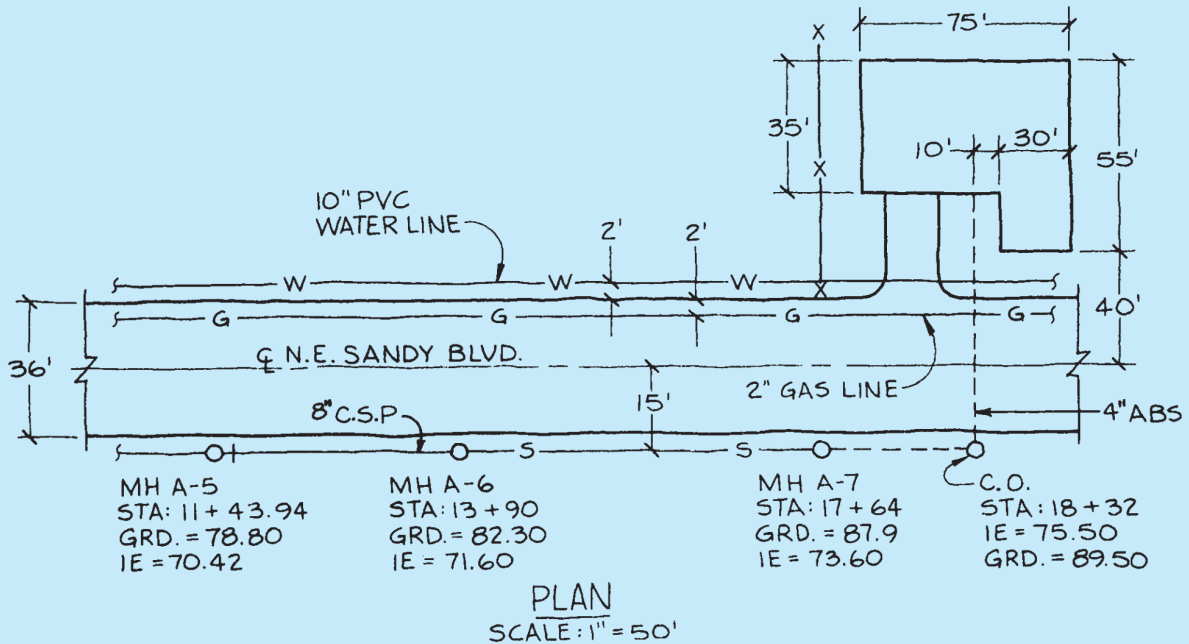


Figure P11-4.

P11-5 Draw the sanitary sewer profile exactly as shown in Figure P11-5. Choose an appropriate size sheet. The profile is also available for download and viewing. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 11-5.pdf.

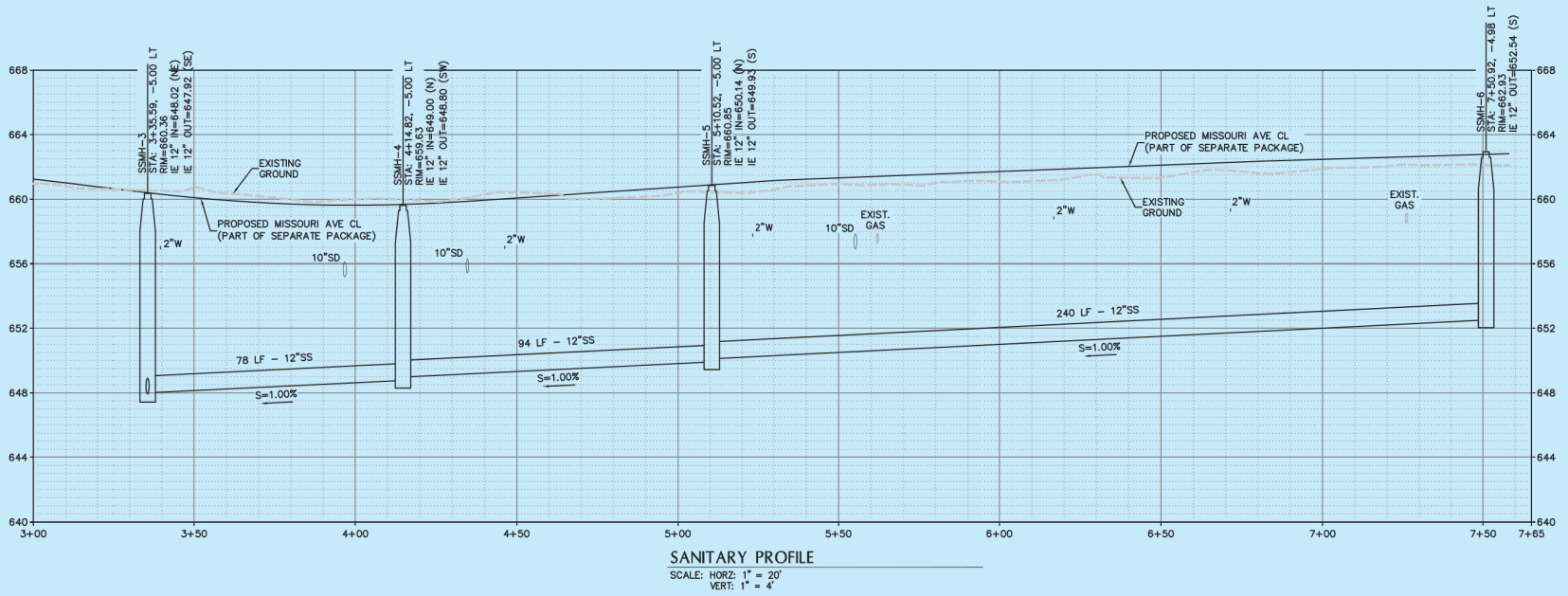
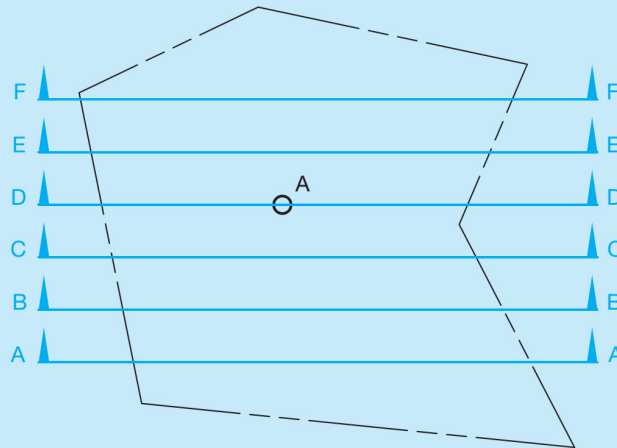


Figure P11-5.
(Courtesy of KPFF Consulting Engineers)

- P11-6** Use the finished drawing from Problem P8-7 to complete this problem. Construct profiles A-A, B-B, C-C, D-D, E-E, and F-F shown in Figure P11-6. Profile D-D cuts through the transit station, point A. The other profiles are 50' apart. Each profile should be only as long as the distance between property lines along the profile. Draw the profiles using a 1" = 100' horizontal scale and a 1" = 10' vertical scale on an appropriate size sheet. Show all profiles on a single sheet. Label vertical elevations and indicate horizontal and vertical scales. Label each profile with a title, such as PROFILE A-A.

Figure P11-6.



- P11-7** Use the finished drawing from Problem P8-6 to complete this problem. Construct a series of profiles across the stream shown in Problem P8-6. Draw the first profile 50' from the southern property line, along the stream, and label the profile A. Label each profile consecutively. Cut each profile perpendicular to the stream and extend the profiles 100' beyond the stream or to the edge of the property. Draw the profiles 25' apart across the entire length of the stream on the property. Determine the best horizontal and vertical scales to use in order to arrange all profiles on an ANSI D size sheet. Use a 10:1 ratio for horizontal and vertical scales. Label elevations on all profiles.
- P11-8** Use the finished drawing from Problem P8-6 to complete this problem. Cut a profile along the stream. Determine the best location for a small dam and pond with a water level that keeps the pond inside the property line. Construct any needed profiles to show the height of the dam and the water line. Add the dam and pond to the map. The drawings submitted for this problem should include the map and profiles and should provide enough information to fully describe the size and location of the dam and pond.
- P11-9** Use the finished drawing from Problem P8-6 to complete this problem. Add a sewer line to the house 30' from the west edge of the house. The sewer connects with a main sewer 30' south of the southern property line. Keep the sewer 10' east of the driveway. Show a cleanout (CO) 10' from the house. Show an additional CO between the house and the main connection, no farther than 100' from the nearest CO. Cre-

ate a plan and profile for the sewer installation. Do not show the entire property. Show contours on the plan. In the profile along the sewer, note the type of pipe, distance between cleanouts, and slope in ft./ft. Choose appropriate scales and an appropriate sheet size. Use the following information for this problem:

- House sewer pipe is 4" ABS
- Sewer main is 8" CSP
- Grade at house is 608'
- Sewer line IE at house is 603'
- IE at house CO is 602.5'
- Grade above sewer main is 584'
- Sewer IE at connection point is 574.80'

P11-10 The vertical curve profile shown in Figure P11-10 provides enough information for you to calculate the elevation of the road at each station point on the vertical curve. Using the formula given in this chapter, make your calculations and record them in the table provided.

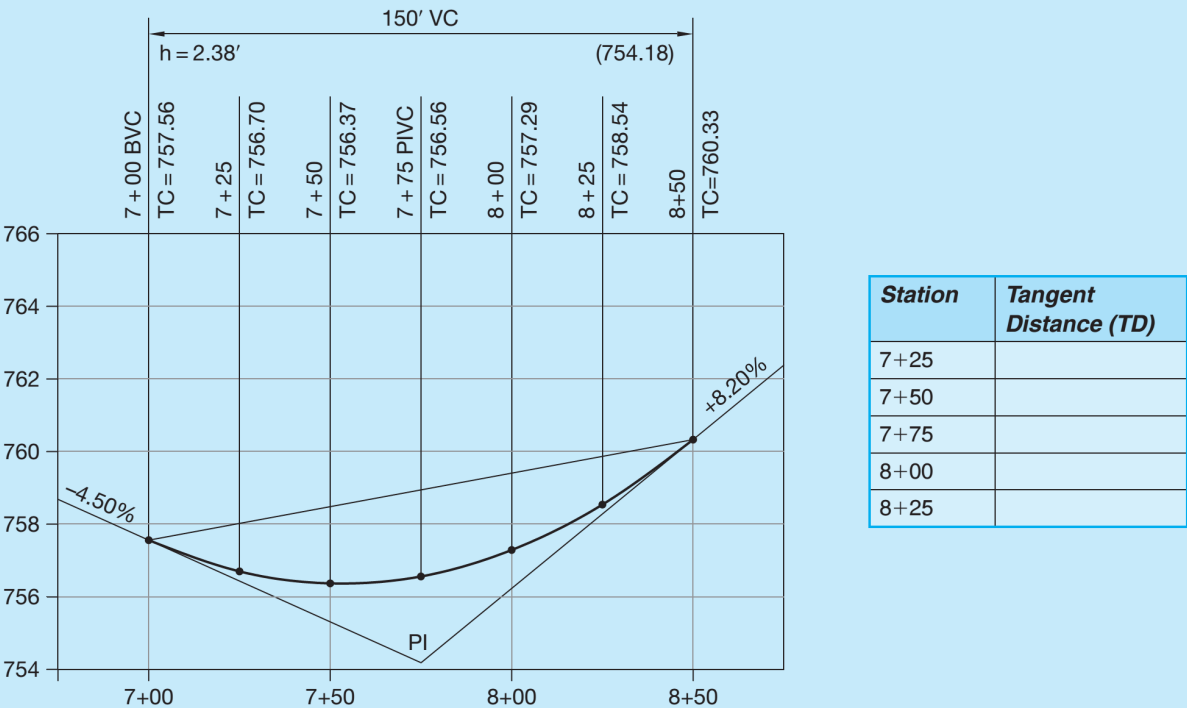


Figure P11-10.

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CHAPTER

12

Earthwork

Learning Objectives

After completing this chapter, you will be able to:

- Define and use angle of repose in a cut and fill drawing.
- Create a cut and fill drawing of a proposed highway and building site.
- Construct cross section drawings using cross section survey data.
- Calculate quantities of earth removed from borrow pits.
- Construct borrow pit excavation grids.
- Calculate earthwork volumes of cross sections using the average end method.
- Describe earthwork design and drafting with civil CADD software.

Key Terms

Earthwork
Crawler dozer
Cut and fill
Grading plan
Angle of repose
Percent slope (S)
Percent grade
Cross section view
Cross section
Profile
Typical cross section
Full station
Breakline
Intermediate foresight (IFS)
Foresight (FS)
Turning point (TP)
Level cross section
Average end method
Borrow pit
3-D chain
Template
Assembly
Daylighting
Daylight line
Corridor
Feature lines
Breakline

Earthwork is a term used in construction to describe quantities of earth excavated from or filled into areas. This chapter describes the layout of earthwork on drawings for civil engineering construction projects. You will explore methods of plotting earthwork and the representations used to display earthwork in plan, profile, and cross section view. You will also learn how volumes of earth are calculated with mathematical formulae.

Cut and Fill

Earthmoving equipment, such as the crawler dozer shown in Figure 12–1, are used in the construction of civil engineering projects to alter the land according to design requirements. A **crawler dozer** is a tracked machine that uses a front-mounted blade to move material, such as dirt. Cut and fill is one of the most common terms associated with earthwork. **Cut and fill** is a term used in construction to describe the method of cutting, or removing by excavating, material from a location to use to fill, or add, material to a different location. Cut and fill usually represents earth that is cut from hillsides and filled into valleys and low areas. Figure 12–2 shows the basic concept of cut and fill. Cut and fill is explained in more detail throughout this chapter.

Note: Cut and fill appears in plan and cross section views. Cut and fill is most often depicted in plan view using a grading plan. A **grading plan** is a construction drawing that generally shows existing and proposed topography.

Route Cut and Fill

Designing and planning the location of a route, such as a road or highway, requires accurately determining how far cuts and fills extend beyond the sides of the road. Cut and fill analysis is important for a variety of reasons such as determining the proper amount of land to purchase for the right-of-way. The following information focuses on the procedure for laying out cut and fill for a proposed level road using a general CADD system such as AutoCAD. This content provides useful information about cut and fill layout and construction.

Cut and fill layout for a roadway begins with plotting the road on a contour map using surveying field data as described in Chapter 10 (see Figure 12–3). The engineer establishes an angle of repose appropriate for the earthwork of the project. **Angle of repose** is the steepest slope at which a specific material is stable (see Figure 12–4). The angle of repose is determined primarily by the type of soil or rock to be cut through or used as fill material. As shown in Figure 12–4, angle of repose can be specified as a horizontal angle or a ratio of run to rise.

Next, establish a cross section view perpendicular to the road as shown in Figure 12–5. Draw lines representing the angle of repose. The example shown in Figure 12–5 uses a 1 1/2:1 angle of repose for areas to be cut and filled. Mark each contour value above and below



Figure 12-1. A crawler dozer is a common example of earthmoving equipment used for the construction of civil engineering projects.

(kavram/Shutterstock)

the road at the point where the contours intersect the slope in the cross section as shown in Figure 12-5.

Now project the points at which the contour values intersect the angle of repose in the cross section onto the plan parallel to the road (see Figure 12-6). Cut and fill boundaries, such as the top of a cut and

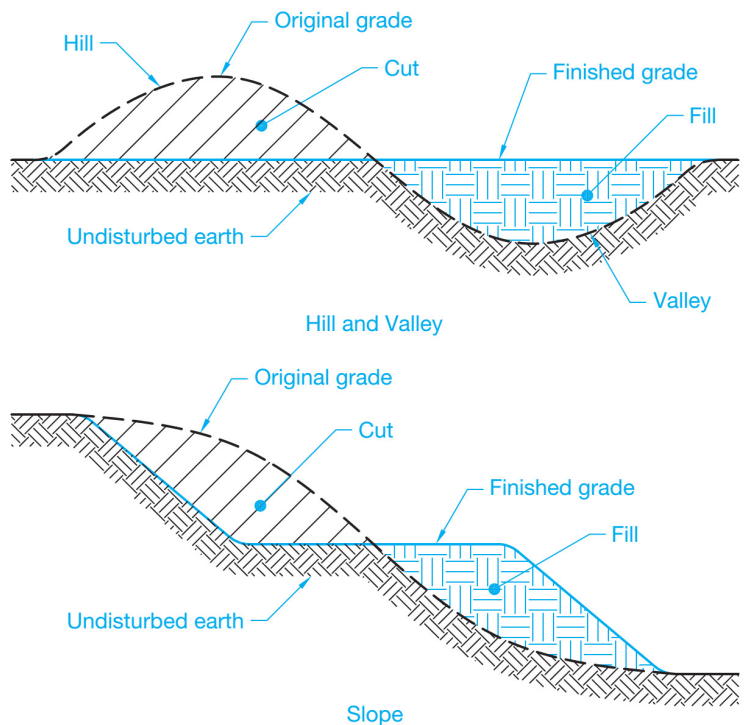


Figure 12-2. Cut and fill is the method of constructing a particular area by cutting material from one area to use as fill material in another area.



Figure 12-3. Begin cut and fill layout by plotting the new road on the plan.

the toe of a fill, are located next. To plot the cut in Figure 12-6, first follow the line projecting from the 105' contour in the cross section up into the map and make a mark where this line intersects the 105' contour line on the map. Do the same with the 110', 115', and 120' contour marks in the cross section. Always follow each line from the cross section completely through the map. The line may cross its contour more than once.

Use this same procedure to plot the cut on both sides of the road and to plot the fill. If cut and fill are the same angle of repose, as in Figure 12-6, the lines projected from the cross section represent both the cut and the fill values. If cut and fill are different angles, it is best to project the cut lines from the cross section only along areas of the map that are above the level of the road. Similarly, project scale lines for fill from the cross section only into areas of the map that are below the level of the road. This prevents the confusion of having two sets of lines along the entire length of the road.

To complete the cut and fill boundaries, begin drawing a line at the intersection of the road and the contour line having the same elevation as the road. Keep the cut and fill boundary line between the lines

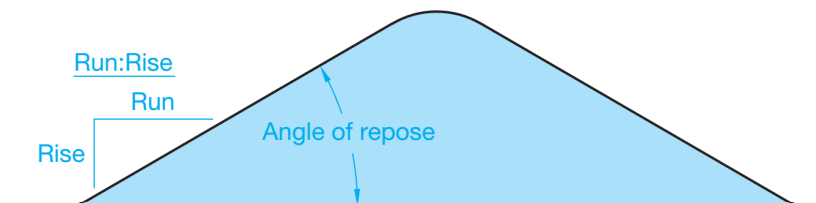
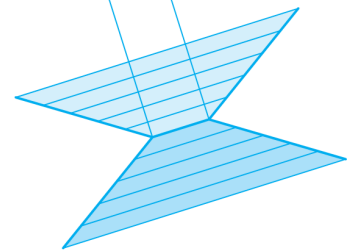
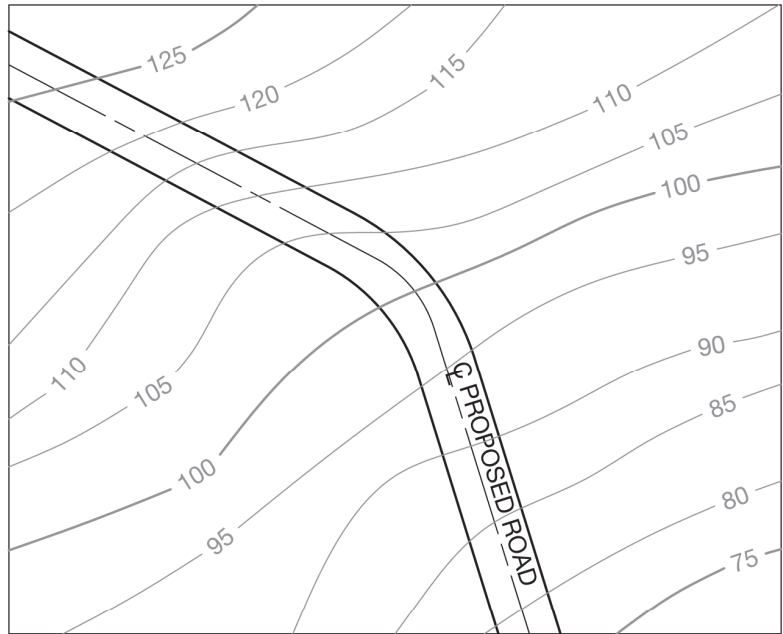


Figure 12-4. Angle of repose is the steepest slope at which a specific material is stable.



Cut and fill cross section

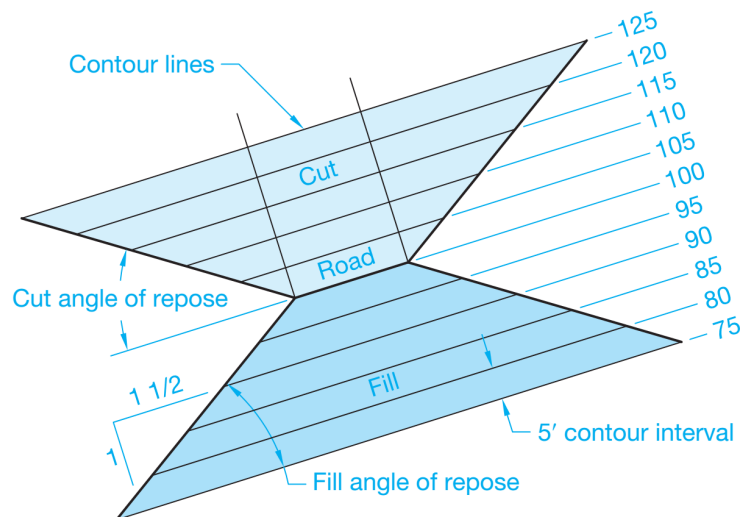
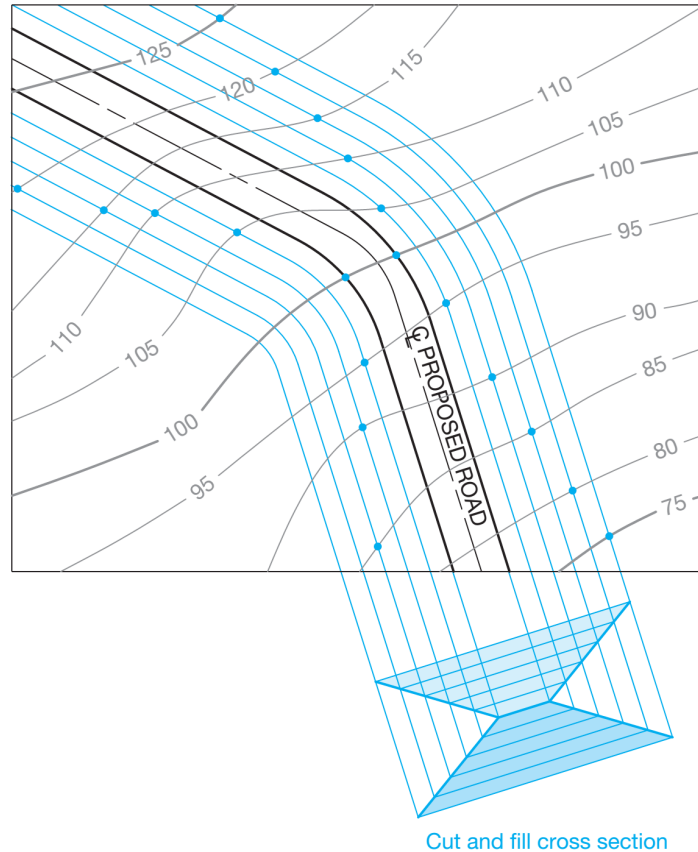


Figure 12-5. Construct a cut and fill cross section perpendicular to the road to define the points at which the contour values intersect the slope. This figure includes an enlarged view of the cross section for reference.

Figure 12-6. Project the points at which the contour values intersect the slope in the cross section view onto the plan, parallel to the road.



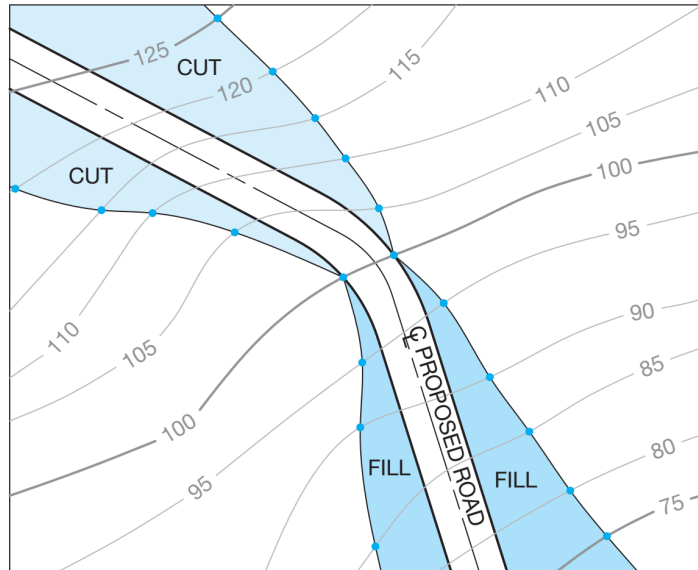
projected from the cross section until you reach the next mark on a contour line (see Figure 12-7). Figure 12-8 shows a pictorial view of the cut and fill example for reference.

Basic Layout Procedure

When using a CADD system such as AutoCAD, you may not need to create the cut and fill profile scale below the map. The following procedure is one method to quickly plot the outlines of cut and fill:

1. Create a layer for the cut scale named Cut Scale, for example, and a layer for the fill scale named Fill Scale.
2. Multiply the angle of repose for the cut by the contour interval. This example uses a 1 1/2:1 angle of repose and a 5' contour interval. $1\frac{1}{2} \times 5 = 7.5'$.
3. Use a command such as AutoCAD's OFFSET command to offset the sides of the road 7.5' multiple times on each side of the road. Be sure to change these offset lines to the Cut Scale layer.
4. Multiply the angle of repose for the fill by the contour interval. This example uses a 2:1 angle of repose and a 5' contour interval. $2 \times 5 = 10'$.

Figure 12-7. Draw the outlines of cut and fill by connecting a line between the intersections of cross section values and map contour lines.

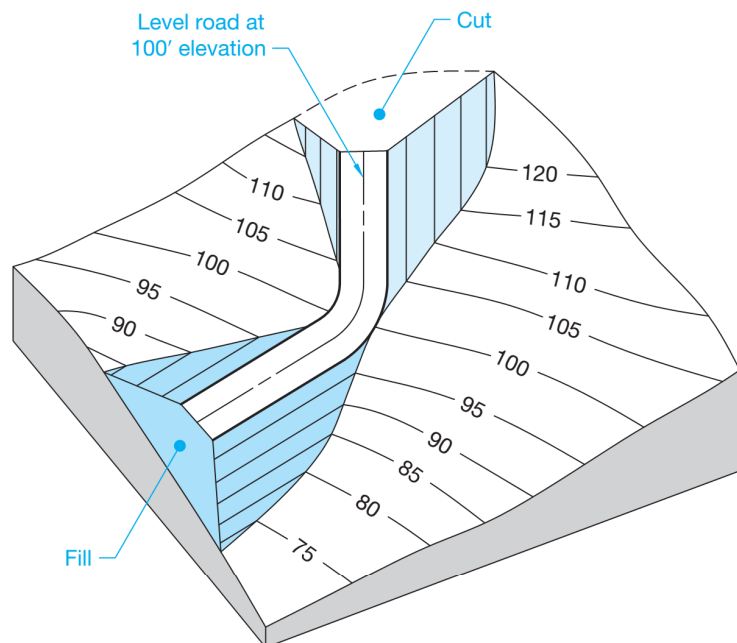


5. Offset the sides of the road 10' multiple times on each side of the road. Be sure to change these offset lines to the Fill Scale layer.
6. Now you have cut and fill scale lines similar to those shown in Figure 12-6 that you can use to plot the outline of cut and fill.

Inclined Road Layout

A plan and profile can be used to establish cut and fill for an inclined road. The road is plotted on the contour map as for a level road as previously described, but a profile of the existing grade along

Figure 12-8. Pictorial view of a cut and fill for reference.



the entire centerline is drawn as shown in Figure 12–9. The grade of the road is determined and plotted on the profile. As explained in Chapter 11, **percent slope (S)**, or **percent grade**, equals $(\text{vertical rise} \div \text{horizontal run}) \times 100$. A 1% grade rises 1' vertically for every 100' of horizontal distance. Therefore, a 100% grade is a 45° angle. In some cases, the slope is given as a vertical rise in feet to horizontal run per foot.

The road shown in Figure 12–9 has a 2.5% grade and a 2:1 angle of repose for both cut and fill. To establish cut and fill, first project the intersections of each contour line and the road centerline from the map to the profile drawing. At the point where the line projected from the road centerline on the map intersects the road grade in the profile, measure vertically from the road to the surface of the natural ground line. For example, project the intersection of the 185' contour from the road centerline in the map to the profile. The measurement along this line in the profile from the road to the natural ground elevation is 5'. Multiply 5' by the angle of repose (2) and place this measurement ($5 \times 2 = 10'$) perpendicular to the edge of the road in the plan view, point A. Project this point parallel to the road to the 185' contour, point B, as shown in Figure 12–9. Do this for all the contours that cross the road in the profile. Then connect the points to delineate the areas of cut and fill.

Site Cut and Fill

Designing and planning the location of a building site also requires determining the limits of cut and fill. The following information focuses on the procedure for laying out cut and fill surrounding a proposed building site, or pad, without using survey profile notes or cross section notes. This procedure can be used to estimate the approximate limits of cut and fill. A series of profile cross sections can be surveyed at the site to determine more exact areas of cut and fill.

First, plot the property boundaries for the proposed site on a contour map using survey data. The elevation of the site after excavation or filling and the required angle of repose are determined by the engineer or designer. This information may be given on the plan as well as bearings and distances for the property lines. Figure 12–10 depicts the site plan layout before application of cut and fill.

Next, determine the areas of cut and fill and plot the appropriate scales for each on the map. In the Figure 12–11 example, the angle of repose for cuts is 2:1 and 1 1/2:1 for fills. The contour interval is 2'. For areas of fill, measure perpendicular to the property lines 1 1/2 times the contour interval, or 3', and draw a line parallel to the property line. For areas of cut, measure perpendicular to the property lines 2 times the contour interval, or 4', and draw lines parallel to the site boundaries (see Figure 12–11).

The elevation for the example site is to be 126'. Areas below this elevation are fill, and areas above are cut. Make a mark where the first line of the fill scale intersects the 124' contour. The second line of the fill scale is the 122' contour. Find all the intersections of like contours

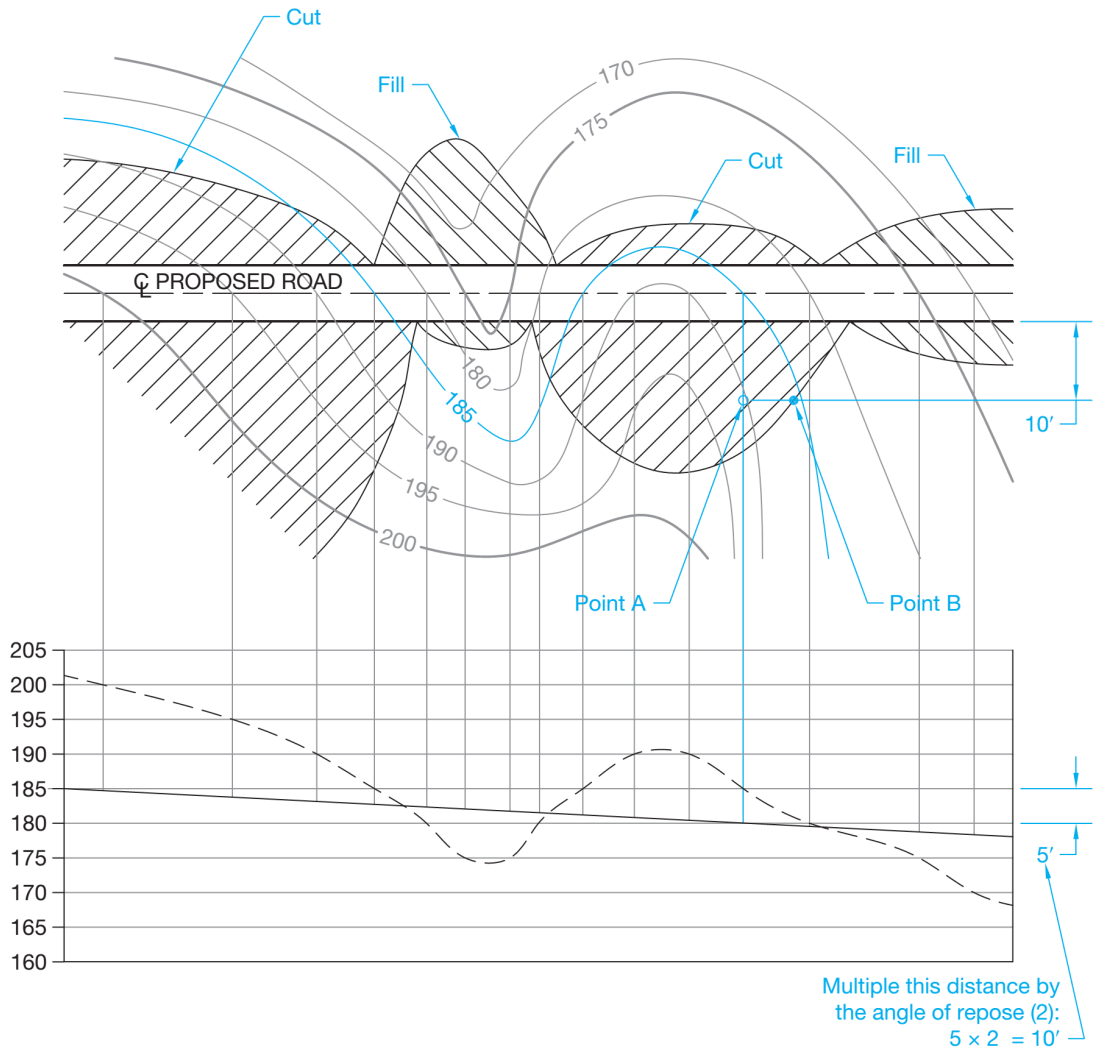


Figure 12-9. Cut and fill layout for an inclined road.

and then connect those points, as shown in Figure 12-12. Use the same technique when finding the required points for the cut. The first line parallel to the property line on the cut scale is 128'. The amounts of excavation and fill can be estimated from this map. Any profiles that are needed can be taken directly from the map. Legends and additional information can be placed on the map as required.

Note: Use a CADD system in the same manner previously described for route cut and fill to quickly add cut and fill scale lines for a site layout. Create layers called Cut Scale and Fill Scale. Then offset the sides of the level pad for both cut and fill, using the formula: $\text{angle of repose} \times \text{contour interval} = \text{offset distance}$. Be sure to change the lines you offset to the appropriate layer before you begin plotting the cut and fill outlines.

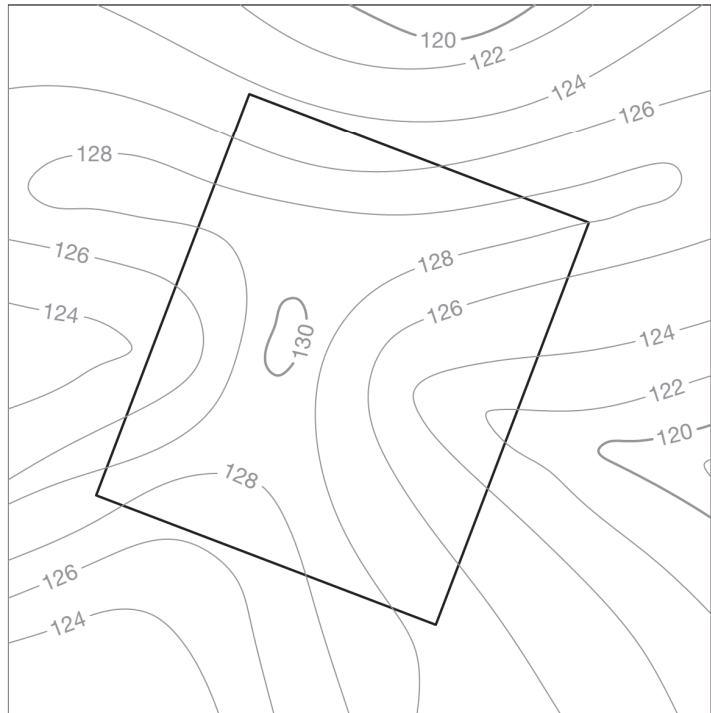


Figure 12-10. Site plan layout before application of cut and fill.

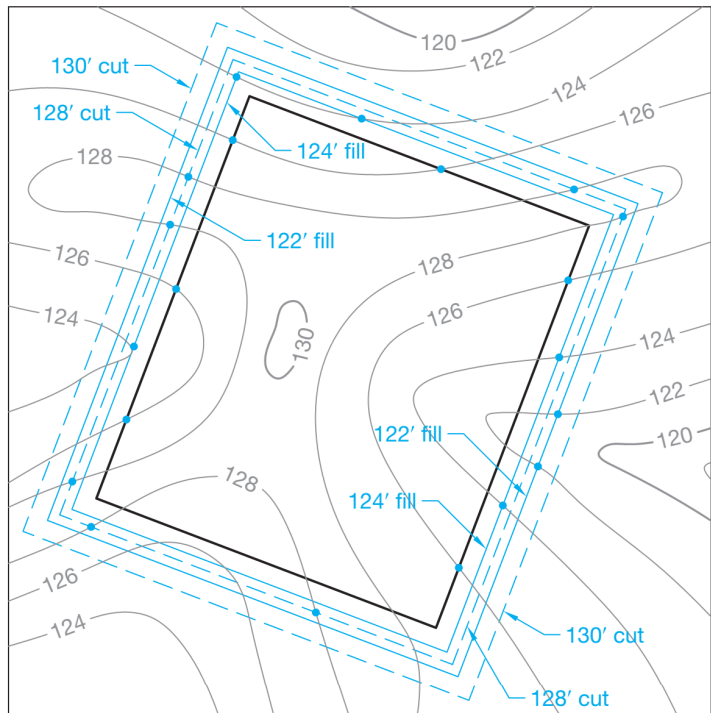


Figure 12-11. Site plan layout with cut and fill scales added.

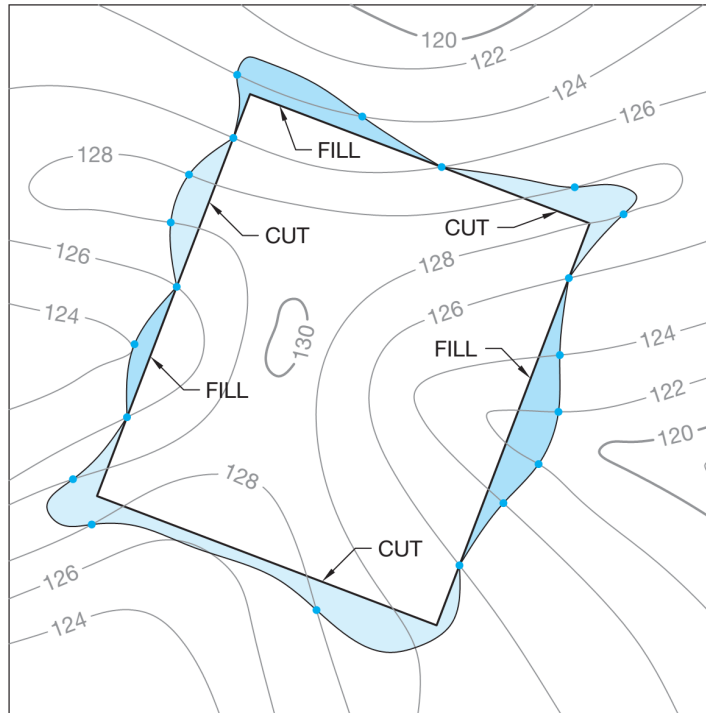


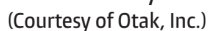
Figure 12-12. Site plan layout showing areas of cut and fill.

Cross Sections

Plans, profiles, and cross sections together provide the design information needed to lay out a civil engineering project (see Figure 12-13). A **cross section view**, or **cross section**, is a view that cuts through an area to show detail that cannot be clearly identified in the plan view. The terms cross section and section are often used interchangeably. Technically, a cross section cuts completely across a feature, while a section cuts through a feature partially or completely. A **profile** is a cross section of a portion of land, or along the length of a linear feature such as a road, sewer line, power line, or stream. Notice in Figure 12-13 that the cross section is a view perpendicular to the profile. Cross sections show a variety of information that does not appear in plan or profile views including slopes, structures, and drainage features. A **typical cross section** is common to any location along the feature such as the street shown in Figure 12-13.

Cross Section Surveys

The previous information about cut and fill layout covers a method used for plotting cut and fill using only basic survey data, such as the route survey of the centerline of a road. In this example, after laying out the roadway, the angles of repose were used to plot the cut and fill. The cross section method of plotting cut and fill is based on field surveys, or lines of levels run perpendicular to the road. These level lines are often short and span only the width of the highway



and areas affected by the cut or fill. Cross sections are important because they provide measurements that can be used for calculating the amounts of earth to be removed from hills and filled into valleys and areas below road grade.

Sections perpendicular to the road centerline are usually measured at full stations, 50' (15 m) stations, and breaklines. A **full station** is 100' (30 m). For example, 2+00 is a full station 200' from the beginning. A **breakline** is a line that defines a change in slope such as a ridge line, the edge of pavement, or a ditch line. A breakline in a route denotes a change in the profile of the centerline. Sections extend far enough from the centerline to include any cut or fill.

The level instrument is set up at a station (STA) that allows several profile measurements to be made from one instrument location. Each foresight (FS) reading along the centerline is noted as an intermediate foresight (IFS). An **IFS** is a separate elevation taken in addition to the run of levels for information purposes. The IFS is located at a station or elevation change. Additional rod readings are taken at set distances perpendicular to the centerline. For example, an IFS reading of 6.4 is recorded on the centerline. Then, the rod is moved 15' perpendicular from the centerline and a rod reading, or FS, of 7.9 is recorded. The **FS** is the rod or target location in surveying to which an elevation and/or location reading is taken. The elevation difference is $-1.5'$ ($6.4 - 7.9 = -1.5$). A second FS of 9.2 is measured 35' perpendicular from the centerline, and the elevation difference from the centerline is $-2.8'$ ($6.4 - 9.2 = -2.8$) (see Figure 12-14). This process is used on both sides of the centerline.

Surveyors try to measure several cross sections before moving to another instrument setup. A turning point (TP) measurement is taken to relocate the instrument. A **TP** is a temporary bench mark such as a large rock, fire hydrant, concrete curb or foundation, wooden stake, or metal spike, on which the rod is rested and used as a pivot for the rod. Several IFS readings can then be taken from one station.

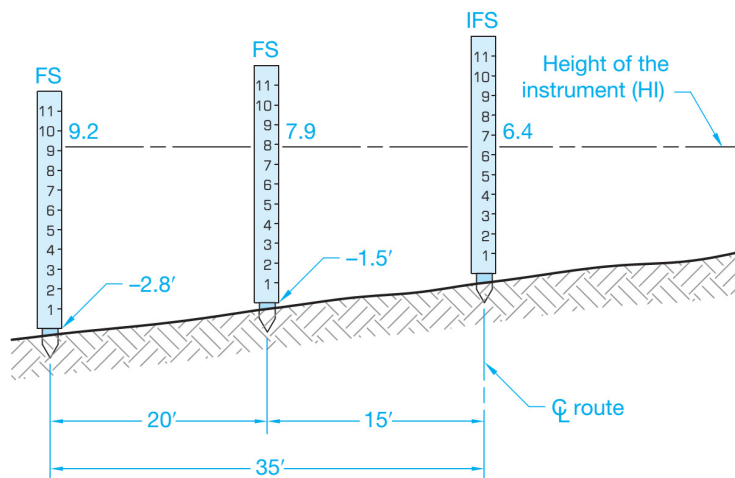


Figure 12-14. Cross section surveys are composed of several elevation measurements taken perpendicular to the centerline of the route.

Cross Sections for Road 213									
STA	BS	HI	FS	IFS	ELEV	Left		Right	
7+00				4.21	877.13	$-\frac{0.8}{35}$	$+\frac{0.4}{15}$	$+\frac{0.5}{14}$	$+\frac{1.9}{35}$
6+50				4.37	876.97	$-\frac{0.2}{35}$	$+\frac{0.5}{16}$	$-\frac{0.9}{15}$	$+\frac{0.4}{35}$
TP	6.22		4.67		875.12				
		881.34							
6+00				5.85	874.01	$-\frac{0.8}{35}$	$-\frac{0.3}{15}$	$+\frac{0.4}{16}$	$+\frac{0.2}{35}$
5+75				5.67	874.19	$-\frac{0.4}{35}$	$-\frac{0.6}{15}$	$+\frac{0.8}{15}$	$+\frac{1.7}{35}$
5+50				5.25	874.61	$-\frac{1.1}{35}$	$-\frac{0.2}{14}$	$+\frac{0.5}{15}$	$-\frac{0.7}{35}$
5+00				4.93	874.93	$+\frac{1.3}{35}$	$+\frac{0.6}{15}$	$-\frac{0.2}{15}$	$+\frac{0.1}{35}$
BM 12	3.62		4.74		876.24				
		879.86							

Figure 12-15. Survey data provides much of the information required to draw cross sections.

Figure 12-15 shows an example of cross section field notes. Notice that the cross section notes contain what appear to be positive and negative fractions. The numerator is the elevation difference from the centerline IFS. The denominator represents the distance of that point from the centerline. The plus or minus indicates whether the point is above or below the elevation of the IFS on the centerline.

Earthwork Calculations

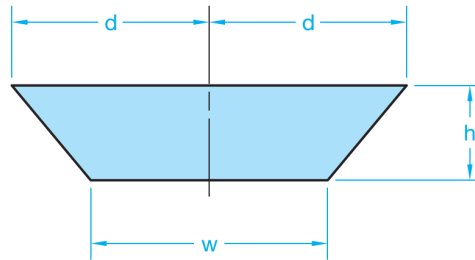
Maps that are drawn using CADD programs and specialized application software can contain enough data for calculating earthwork volumes. These procedures, based on computer-generated data, are often sufficient for construction and estimating purposes. However, it is important for you to understand the nature of cross section area calculations and to be able to calculate volumes of earthwork in cut and fill.

A **level cross section** is one in which the ground is basically level, and the height, or depth, of the cut is constant across the profile. The area (A) of a level cross section is calculated by figuring the average of the top (d) and bottom (w) widths and multiplying this by the height (h) of the cut or fill (see Figure 12-16). Apply the following formula for these calculations:

$$A = h \left(\frac{2d + w}{2} \right)$$

$$A = h \left(d + \frac{w}{2} \right)$$

Figure 12-16. The area of a level cross section is calculated by using the dimensions of the profile.



A cross section that is not level but has three distinct levels, is calculated by finding the area of triangles (see Figure 12-17). Use the following formula for these calculations:

$$A = \left(\frac{1}{2}\right)\left(\frac{w}{2}\right)(h_1 + h_2) + \left(\frac{1}{2}\right)(c)(d_1 + d_2)$$

$$A = \frac{w}{4}(h_1 + h_2) + \frac{c}{2}(d_1 + d_2)$$

The previous two formulae allow you to calculate the area of a cross section. These areas can then be used to calculate earthwork volumes. The **average end method** uses the averages of the two end cross sections to compute the volume of earth between the sections. The volume (V) is equal to the average area of the two cross sections (A_1 and A_2) multiplied by the distance between the two (D). One cubic yard equals 27 cubic feet. Divide cu. ft. by 27 to obtain cu. yd.:

$$V = \left(\frac{A_1 + A_2}{2}\right)\left(\frac{D}{27}\right)$$

The following examples illustrate how averages can be calculated for the two cross sections shown in Figure 12-18. The averages are then used to calculate the earthwork volumes between the two sections.

Section 8+00:

$$A = \frac{w}{4}(h_1 + h_2) + \frac{c}{2}(d_1 + d_2)$$

$$A = \frac{15}{4}(15 + 12) + \frac{8}{2}(32 + 27)$$

$$A = 101.25 + 236 = 337.25 \text{ sq. ft.}$$

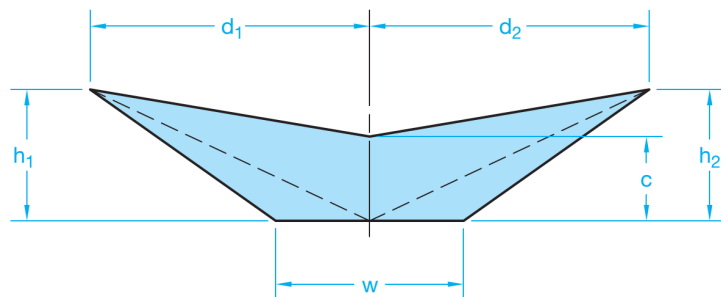


Figure 12-17. The area of cross sections that are not level but that have three distinct levels are calculated by finding the area of triangles.

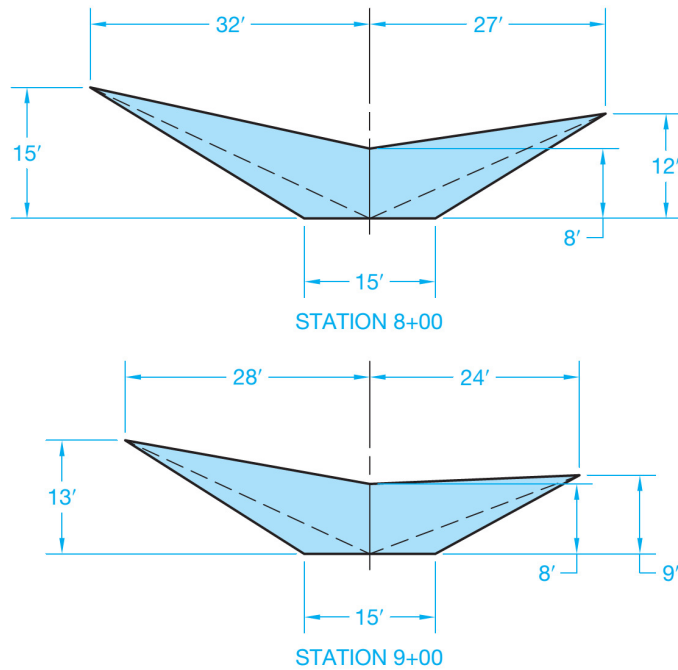


Figure 12-18. The volume of earth between these two cross sections is 1,161.36 cu. yd.

Section 9+00:

$$A = \frac{w}{4}(h_1 + h_2) + \frac{c}{2}(d_1 + d_2)$$

$$A = \frac{15}{4}(13 + 9) + \frac{8}{2}(28 + 24)$$

$$A = 82.5 + 208 = 290.5 \text{ sq. ft.}$$

Now that the areas of the two sections have been determined, an earthwork calculation for the volume of material between the two sections can be made. The following formula allows you to find the volume in cubic yards. In this formula, A equals the area of a cross section, and D is the distance between cross sections:

$$V = \left(\frac{A_1 + A_2}{2} \right) \left(\frac{D}{27} \right)$$

$$V = \left(\frac{337.25 + 290.5}{2} \right) \left(\frac{100}{27} \right)$$

$$V = 313.88 \times 3.70 = 1,161.36 \text{ cu. yd.}$$

Borrow Pits

A **borrow pit** is an excavation from which material is removed and used as fill elsewhere. Borrow pits are often visible at interchanges along interstate highways. They can appear as square, rectangular, or trapezoidal ponds because they often fill with water. Accurate

calculations of borrow material are important because the contractor is paid based on the amount of earth removed. The price per cubic yard is multiplied by the number of yards excavated and hauled.

A borrow pit is defined by laying out a grid. The size of the grid is determined by the amount of material needed, the type of soil, and the land available. The grid is composed of squares with sides of 20' (6 m), 40' (12 m), 50' (15 m), or 100' (30 m) (see Figure 12-19). The elevations of each grid intersection are determined by running levels. Reference points, or hubs, are established on extension lines beyond the limits of the grid. Using these reference hubs, the grid can be easily relocated after the excavation.

The elevations of the grid intersections are determined after excavation by running levels again. The heights of the cut are recorded for each intersection, as shown in Figure 12-19. These values can then be used to determine the quantity of borrow material. The quantity of earthwork in one of the squares is calculated by multiplying the area of the section by the average of cut depths at each corner. For example, in Figure 12-19, the square A1, A2, B1, B2 is 50' × 50', or 2,500 sq. ft. The average depth of its four corners is calculated using the following formula:

$$\frac{4.2 + 3.8 + 3.6 + 3.1}{4} = 3.675$$

Multiply 2,500 by 3.675 and the result is 9,187.5 cu. ft. One cubic yard equals 27 cubic feet. Divide cu. ft. by 27 to obtain cu. yd.:

$$\frac{9,187.5}{27} = 340.28 \text{ cu. yd.}$$

The most accurate calculations can be obtained by following this procedure for each square in the grid. The procedure can be simplified by combining squares of the same dimensions. For example, to find the material in the larger square of A1, A3, C1, C3, you must find the average of all the corner depths for four squares. Corners that are common to more than one square must be added for each square. The total of the corner depths for the large square just defined is 52.8

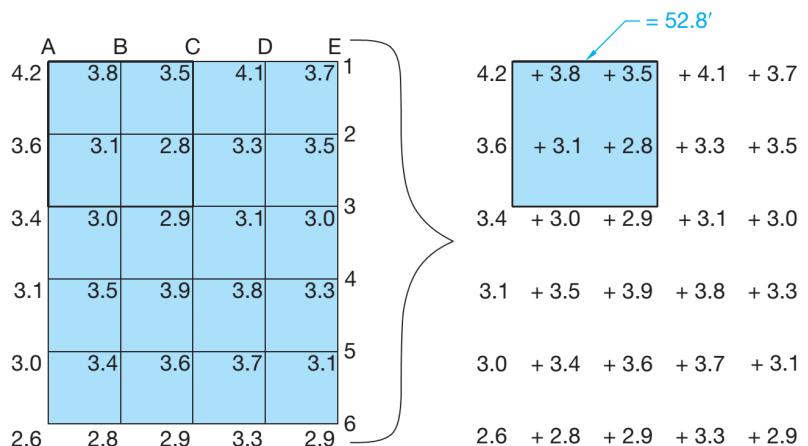


Figure 12-19. The borrow pit is laid out as a grid, and the final excavation depths are labeled at each grid intersection.

(see Figure 12–19). Divide 52.8 by 4, and the average sum of the cut depths for the individual squares is 13.2'. The formula for determining the amount of material is:

$$\text{Area of section} \times \text{Average of corner depths} = \text{Cubic feet}$$

The number of cubic yards is then calculated as follows:

$$\frac{\text{Cubic feet}}{27} = \text{Cubic yards}$$

The values in the previous example are calculated as follows:

$$13.2 \times 2,500 = 33,000 \div 27 = 1,222 \text{ cu. yd.}$$

Drainage Considerations

When developing site grading plans, the most essential factor to consider is drainage. Determining how water will flow on the site and exit the site is critical. A hydrologic study of the existing conditions of the site includes data about the type of soils and ground cover present, how water flows on the site, how much water is absorbed, and the volume and direction of water leaving the site.

An analysis of these factors must also be assembled based on the proposed design. For example, there are major impacts to consider when a field or forest is replaced with a paved parking area. Much less water is absorbed into the ground and hence exits the site. The water is also contaminated from flowing across the asphalt. Drainage collection basins and pools are often constructed to prevent contaminants from flowing into watersheds. These collection basins are often landscaped with plants that absorb and clean pollutants from the water. In addition, ponds and basins hold water long enough to allow for evaporation of some pollutants.

The effects of different amounts of rain are calculated to determine what are known as 1-year, 10-year, 50-year, and 100-year storms. A 1-year storm is the worst storm that is likely to occur in a 1-year period, a 10-year storm is the worst storm that is likely to occur in that time period, and so on. Careful design assessments are also made to impacts on wetland areas, including direct impact from earthwork on the site and drainage from a site flowing into existing wetland areas.

Earthwork with Civil CADD

The combination of a horizontal alignment, described in Chapter 10, and profile, explained in Chapter 11, provide a three-dimensional (3-D) path that a typical road section can be extruded along. In AutoCAD Civil 3D, for example, the path is known as a **3-D chain**. In a CADD environment, a typical road section for a road design taken from a 3-D path is referred to as a **template**, or in the case of AutoCAD Civil 3D, an **assembly**. The CADD program builds a 3-D model of the road by inserting the template along the alignment-profile 3-D path at regular intervals.

Dynamic elements that seek out a terrain model that represents the existing ground elevations are usually attached to the left and

right ends of the template. These elements will create a transition from the design elevation of each template to the existing elevation of the surface at a point perpendicular to the road alignment. The transition can be a straight line transition in the form of a cut or fill slope, or it can be more complex, including ditches, berms, and other features. This functionality of seeking out and intersecting with existing ground is often referred to as **daylighting**.

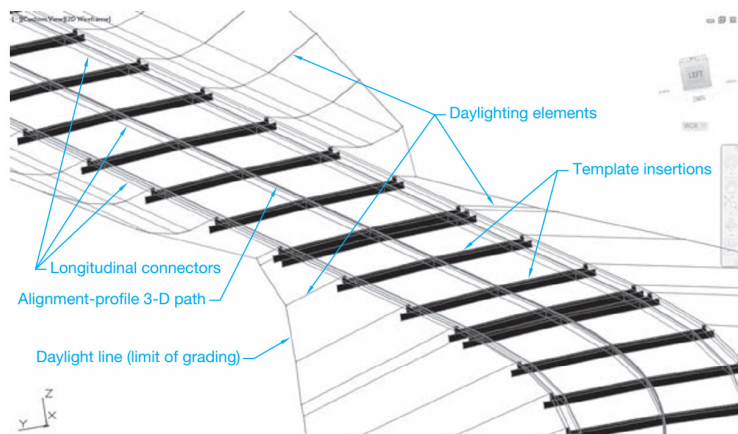
In the longitudinal direction, similar points are connected with 3-D lines to form the edges of the road model. For example, the points on each assembly insertion that represent the flowline of a curb are connected to draw the 3-D edge representing the curb flowline. This is done for the top-face of the curb, top-back of the curb, ditch edges, shoulder edges, or whatever cross sectional road features may be present in the template. The longitudinal line connecting all of the daylight points, often referred to as the **daylight line**, is of special importance. The daylight line represents the limits of grading for the proposed road. The assembly insertions and longitudinal connectors comprise a dynamic system that represents a 3-D design model of the road. In AutoCAD Civil 3D, for example, this dynamic system is referred to as a **corridor** and it dynamically responds to changes in the alignment, profile, configuration of the template, and/or formation of the existing ground surface. Figure 12–20 shows a 3-D view of an AutoCAD Civil 3D corridor.

As a final step, the longitudinal connectors, referred to as **feature lines** in AutoCAD Civil 3D, can serve as breaklines, and through an automated process, the 3-D road model can be represented by a terrain model, DTM, or TIN surface. A **breakline** is a line that defines a change in slope such as a ridge line, the edge of pavement, or a ditch line. Figure 12–21 displays a 3-D view of a surface in AutoCAD Civil 3D that was created from the corridor shown in Figure 12–20.

Templates

A CADD environment typically offers tools to make the process of creating a typical section for a road design, or template, more automated and efficient. In the case of AutoCAD Civil 3D, for example,

Figure 12–20. A 3-D view of an AutoCAD Civil 3D corridor.
(Courtesy of Eric Chappell and Autodesk, Inc.)



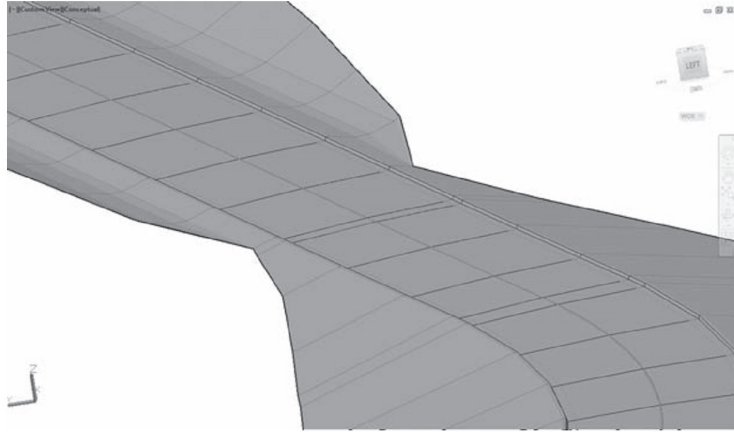


Figure 12-21. A 3-D view of a surface in AutoCAD Civil 3D that was created from the corridor shown in Figure 12-20.
(Courtesy of Eric Chappell and Autodesk, Inc.)

the software employs subassemblies such as curbs, lanes, ditches, embankments, and other cross sectional road features as “building blocks” which “snap” together to build the road assembly in a gradual fashion (see Figure 12-22).

In many cases, subassemblies are more than just geometric representations of the features they stand for, and often have built-in automated behaviors like the ability to daylight with a surface, find and attach an alignment, or build out a series of benches on a steep cut or fill slope. The dynamic capabilities of subassemblies enable road design models to vary dramatically in nearly any geometric respect, without being confined to a single, uniform cross section throughout the length of the road.

Cross Sections

Cross sections have long been a critical method for documenting and representing the design of roads. In traditional road construction, the road is built by recreating the cross sections shown on the section sheets at regular intervals and at key stations. By staking out the station, offset, and elevation of edge-of-pavement, back-of-curb,

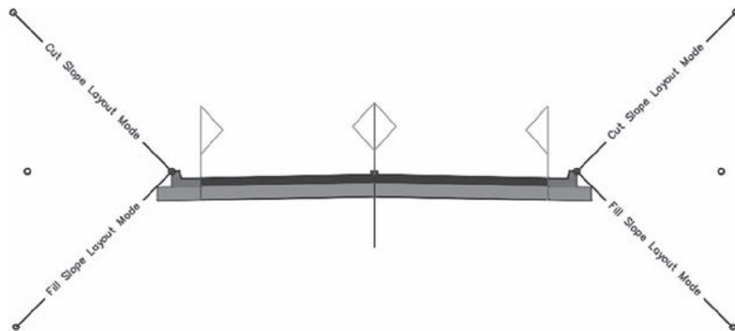


Figure 12-22. An AutoCAD Civil 3D assembly.
(Courtesy of Eric Chappell and Autodesk, Inc.)

invert-of-swale, and other points, a contractor can represent a road in the field, one cross section at a time. In a similar manner, cross sections are used as a design medium for roadway engineers to develop the road. Figure 12–23 shows a street cross section.

Since the advent of CADD programs, cross sections are no longer essential in designing the road. However, cross sections are still a critical part of documentation and earthwork calculation. CADD programs automate the process of sampling, generating, and arranging cross sections to save the designer or engineer as much time and tedium as possible. AutoCAD Civil 3D software, for example, automatically generates sample lines at regular intervals along an alignment which represent locations where the road design will be “sliced” to create a cross section. Cross section grids, called views, which house the slice of the design road, existing surface, underground infrastructure, and other items are created using another automated series of commands. These same commands can also arrange the cross section grids based on a given sheet size and printable area (see Figure 12–24). A well-configured system allows cross section sheets for a road design to be generated and plotted much faster than traditional methods.

Cross Sectional Volume Calculations

Cross sections are used for documentation, and are also vital in performing earthwork and material volumes for a road design. CADD programs can automate methods such as the average end area method by quickly determining the areas of cuts, fills, or material “slices” at each cross section, computing the volume between cross sections, and ultimately tallying the volume along the entire corridor. The repetitive and mathematical nature of this method makes it perfect for automation using a computer. A CADD program such as AutoCAD Civil 3D can quickly generate material volume and

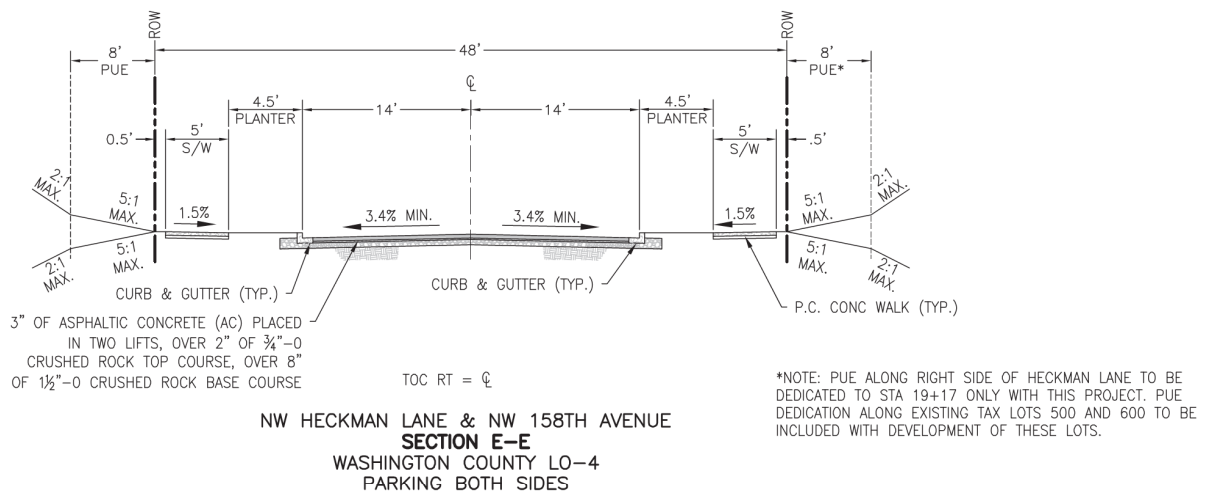


Figure 12–23. A typical street cross section.
(Courtesy of Otak, Inc.)

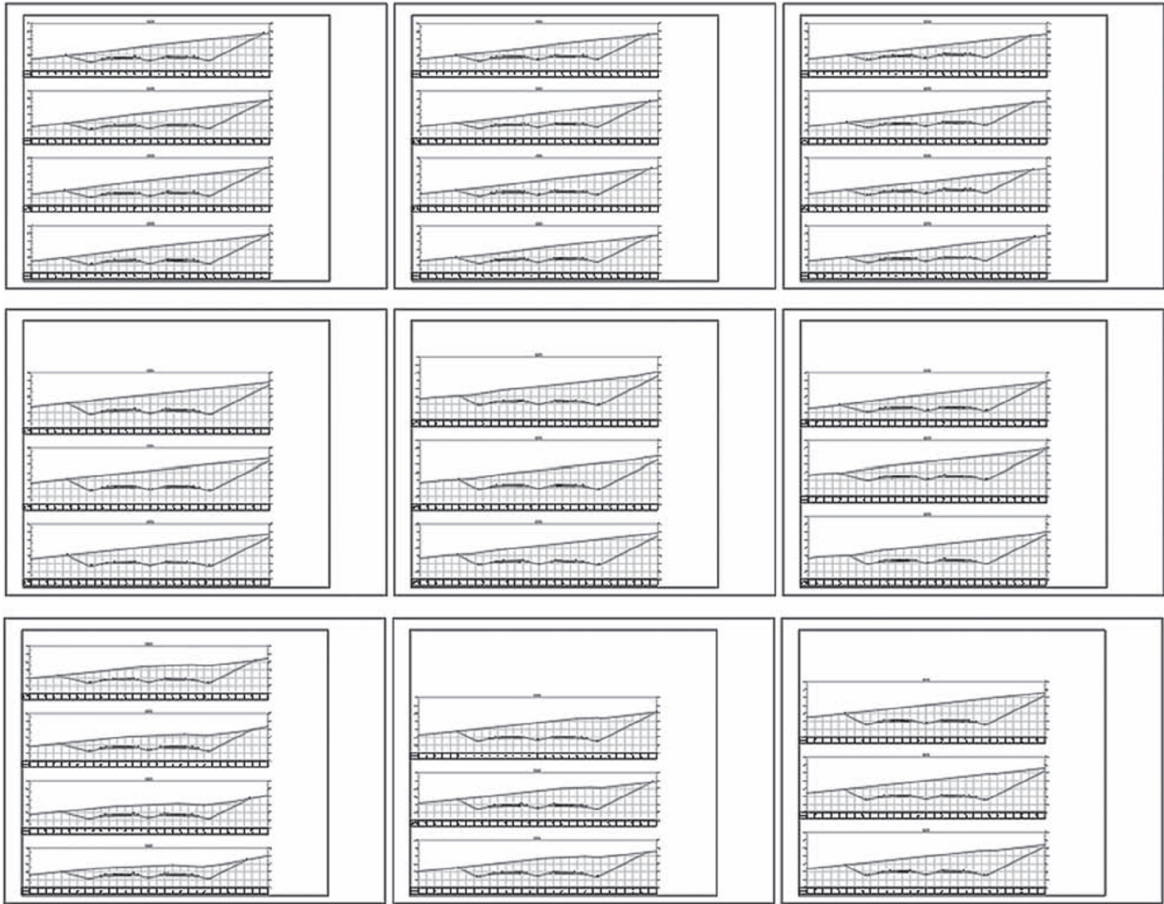


Figure 12-24. Section sheets automatically generated in AutoCAD Civil 3D.

(Courtesy of Eric Chappell and Autodesk, Inc.)

cut/fill volume results and calculate and illustrate mass-haul for a given road design.

Grading and Volumes for Site Design

Regardless of the project type, development typically involves some change to the shape of the earth. In the case of roads, the process is long and linear with a relatively uniform cross section. In contrast, site design is not long, linear, or uniform. For this reason, the approach used to shape the land and determine earthwork volumes is quite different for site design.

The act of shaping the land in site design is often referred to as grading and the tools that automate and improve this type of work are often referred to as grading tools. Many of the grading tools optimize or automate the process of creating points and/or breaklines, which ultimately become components in a TIN surface. For example, AutoCAD Civil 3D provides a tool called a grading object, which automatically generates a cut or fill slope that extends from a 3-D line to a surface representing existing ground (see Figure 12-25).

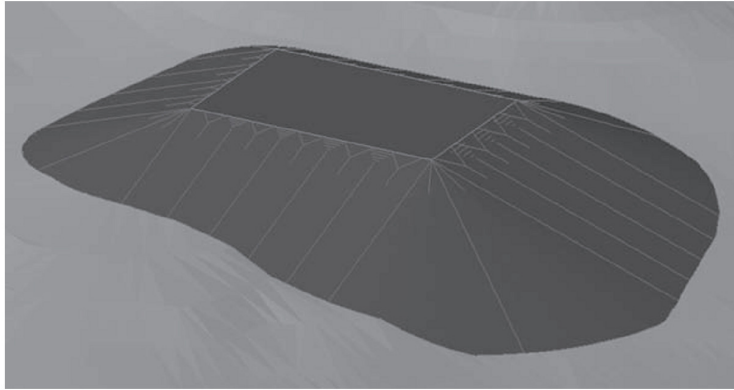


Figure 12-25. An AutoCAD Civil 3D grading object.

(Courtesy of Eric Chappell and Autodesk, Inc.)

This automates the process of establishing the daylight line where the slope intersects the surface and provides a breakline along the limits of grading.

Site grading is essentially a process of creating a TIN surface with 3-D geometric forms specified by the designer, not based on data collected in the field as with an existing ground surface. A more traditional form of grading involves drawing contours and labeling spot elevations that represent the proposed ground elevations. Although this approach does not take advantage of the automated grading tools that most CADD programs provide, it is still popular due to its simplicity and the easier transition from the manually drawn form of the same approach. CADD programs typically have tools that can build a TIN from the contours that have been drawn by a traditional grading designer.

Volume calculation for site design is also different from road design. Site volume calculations are performed with a CADD program using algorithms that compare the existing ground surface to the finished ground surface and calculate the volume of cut and fill based on that comparison, instead of using cross sections. This TIN comparison method is highly accurate, provided the TIN surfaces that are being analyzed are also accurate. This method could be applied to roads as well but typically is not due to the requirements of providing a mass-haul analysis and generally showing volume data as it progresses along the road design.

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Answer the following questions.

- 12-1** What is earthwork?
- 12-2** What is cut and fill?
- 12-3** What determines the slope of a cut?
- 12-4** What is the slope of a cut and fill called?
- 12-5** What is percent slope?
- 12-6** What is a cross section?
- 12-7** What is an intermediate foresight?
- 12-8** How many IFS readings can be taken from a single instrument setup?
- 12-9** Write the correct field notes notation for an IFS reading that is 25' from the centerline and 2.6' below the elevation of the centerline.
- 12-10** What is a level cross section?
- 12-11** Describe the average end method of computing earth volumes.

12-12 Define borrow pit.

12-13 What determines the size of a borrow pit?

12-14 What is the meaning of the numbers recorded at the intersections of a borrow pit grid?

12-15 Write the formula for obtaining the cubic feet in a borrow pit and the formula for converting cubic feet into cubic yards.

Part 2

Study the portion of the site and grading plan shown in Figure R12-1 to answer the following questions. The drawing is also available for download and viewing, which is likely necessary to see the required detail. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Chapter 12 Site and Grading Plan.pdf.

12-16 The plan has a _____ scale and the section has a _____ scale.

12-17 This drawing is number _____ and is sheet _____ of _____ sheets in a set of drawings.

12-18 The elevation of the 12'L × 4'W × 6'H concrete wall footing left in place is approximately _____ based on the closest contour line.

12-19 The elevation at the retaining wall of the southeast corner of the square-shaped open reservoir is approximately _____.

12-20 The rim elevation of catch basin #1 is _____ and the elevation at the bottom inside of the pipe is _____.

12-21 Entry road curve 2 has an included angle of _____, a radius of _____, and an arc length of _____.

12-22 Entry road line 3 has a bearing angle of _____ and a length of _____.

12-23 The project site area is _____ sq. ft. or _____ acres.

12-24 The net amount of cut and fill is _____ cu. yd. based on _____ cu. yd. of cut material and _____ cu. yd. of fill material.

12-25 The elevation at the top of the reservoir tank is _____.

12-26 A 2.5' retaining _____ surrounds the _____ southwest of, and closest to the tank.

12-27 The angle of repose for a swale off the edge of a typical road has a _____ ratio.

12-28 The percent slope of a typical road is _____.

12-29 The thickest dashed line on the plan denotes the _____.

12-30 The thickest phantom line on the plan denotes the _____.

Figure R12-1.
(Courtesy of PACE Engineers, Inc.)

PROBLEMS

Follow the specific instructions to complete each problem.

- P12-1** Draw the required cut and fill for the construction of the proposed 40' wide level road shown in Figure P12-1. The elevation of the road is 270'. The angle of repose for cut and fill is 2:1. Plot the drawing at a scale of 1" = 50' on an architectural B size sheet. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 12-1.dwg file to reference the plan.

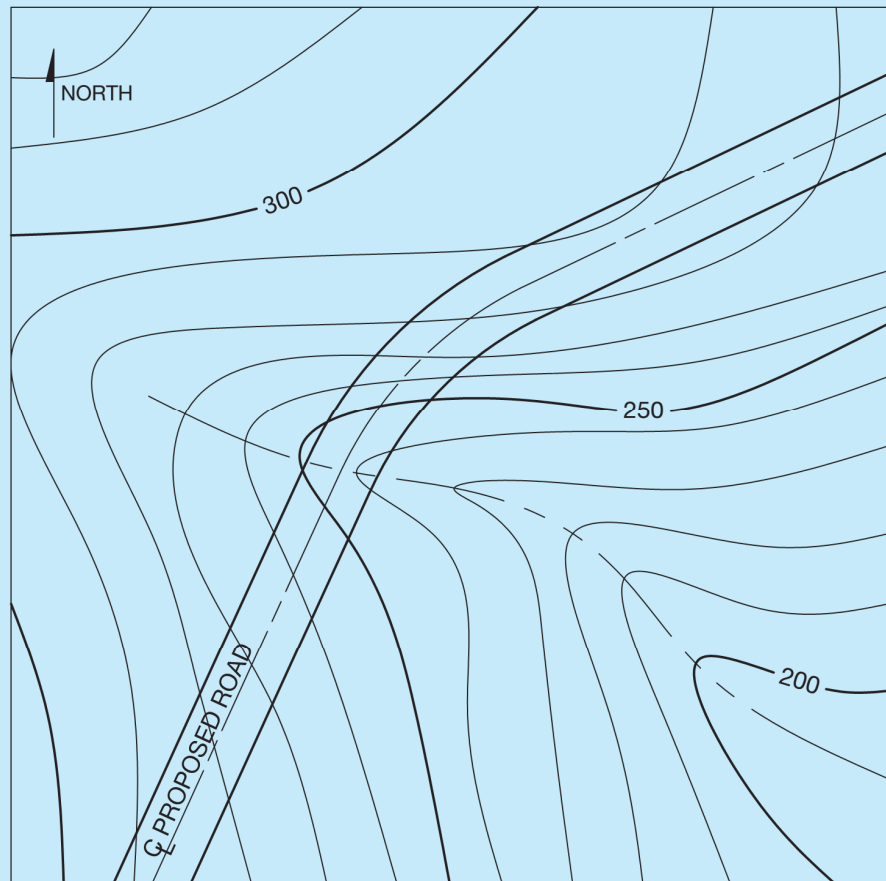
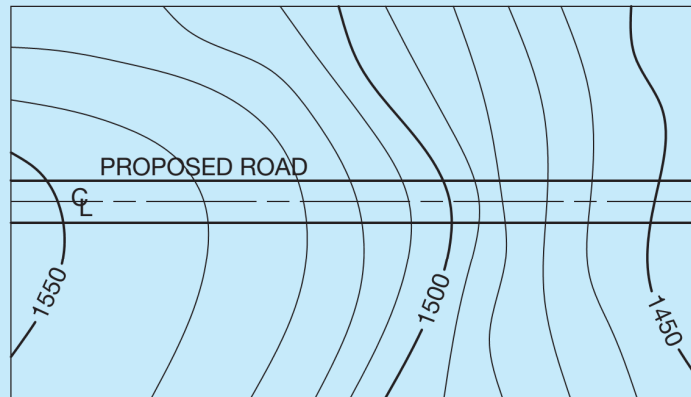


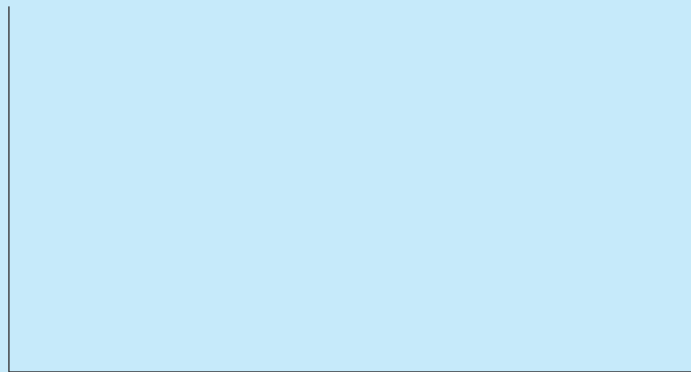
Figure P12-1.

P12-2 Draw the required cut and fill for the construction of a 36' wide inclined road. You are given the plan shown in Figure P12-2 and must construct a profile from which to calculate cut and fill. The road is to have a 6% grade, and the cut and fill begins at elevation 1500'. The angle of repose for cut and fill is 2:1. Plot the drawing at a scale of 1" = 50' on an ANSI B size sheet. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Problem 12-2.dwg file to reference the plan.

Figure P12-2.



Plan



Profile

A topographic map showing a region with a rectangular boundary. The boundary is a dark line that is slightly tilted, with its corners at approximately (210, 350), (790, 670), (340, 810), and (210, 350) in normalized coordinates. The map features several contour lines, which are thin, dark, wavy lines representing elevation. Two specific contour lines are labeled: '650' on the left side and '600' on the bottom right. The background is a light blue color, and the overall shape of the map is irregular, following the contours of the terrain.

P12-4 Use the finished drawing from Problem P10-3 to complete this problem. Draw the required cut and fill for the construction of the proposed level road. The elevation of the road is 530'. The angle of repose for cut is 1 1/2:1 and for 2:1 fill.

P12-5 The measurements in the table shown in Figure P12-5 were surveyed on a grid for a borrow pit. The first column in the table represents the grid location. “Existing Elevation” is the elevation before excavation, and “Finish Elevation” is the elevation after excavation. The grid spacing is 50’. Grid lines A–F run north and south. Draw the borrow pit grid to scale on an ANSI B size sheet. Label the grid values and label the cut depths at each grid intersection. Calculate the total amount of excavated material in cubic yards and place the value on the drawing.

Grid	Existing Elevation	Finish Elevation	Grid	Existing Elevation	Finish Elevation
A1	236.2	233.1	D1	238.3	231.5
A2	235.8	232.8	D2	237.6	232.2
A3	237.0	233.1	D3	236.9	231.8
A4	236.9	234.5	D4	239.2	234.1
A5	237.1	233.9	D5	240.2	235.4
A6	238.2	234.1	D6	238.7	234.1
B1	237.1	233.0	E1	238.3	234.0
B2	238.2	234.0	E2	239.2	235.6
B3	239.4	235.3	E3	237.5	233.2
B4	238.7	233.9	E4	239.7	234.2
B5	239.6	235.2	E5	240.8	235.2
B6	240.1	236.4	E6	241.3	235.9
C1	240.8	235.4	F1	241.3	236.5
C2	239.8	234.5	F2	240.6	236.1
C3	239.5	234.2	F3	239.8	235.3
C4	240.3	236.1	F4	240.7	236.2
C5	239.1	234.8	F5	241.3	237.8
C6	240.6	236.0	F6	240.6	235.9

Figure P12-5.

P12-6 The measurements in the table shown in Figure P12-6 were surveyed on a grid for a borrow pit. The first column in the table represents the grid location. “Existing Elevation” is the elevation before excavation, and “Finish Elevation” is the elevation after excavation. The grid spacing is 20’. Grid lines A–F run north and south. Draw the borrow pit grid to scale on an ANSI B size sheet. Label the grid values and label the cut depths at each grid intersection. Calculate the total amount of excavated material in cubic yards and place the value on the drawing.

<i>Grid</i>	<i>Existing Elevation</i>	<i>Finish Elevation</i>	<i>Grid</i>	<i>Existing Elevation</i>	<i>Finish Elevation</i>
A1	547.3	543.1	D1	546.3	542.8
A2	546.7	642.6	D2	546.9	543.1
A3	546.8	541.9	D3	547.3	544.0
A4	546.3	541.5	D4	547.6	543.8
A5	547.4	542.8	D5	547.9	544.2
A6	547.7	543.1	D6	547.5	543.8
B1	548.3	544.2	E1	548.4	544.3
B2	548.5	544.8	E2	548.2	543.7
B3	548.9	544.6	E3	548.0	544.3
B4	548.2	543.9	E4	547.8	543.4
B5	547.4	543.7	E5	547.9	544.0
B6	547.8	543.6	E6	547.5	543.2
C1	547.3	543.1	F1	547.8	543.1
C2	547.0	542.8	F2	548.2	543.9
C3	547.0	542.5	F3	548.5	544.6
C4	546.8	542.3	F4	548.3	544.0
C5	546.4	542.0	F5	548.8	544.7
C6	546.1	542.1	F6	548.3	544.8

Figure P12-6.

P12-7 Plot cross sections for each of the profiles listed in the field notes in Figure 12-15. Use a single ANSI D size sheet or two ANSI C size sheets for the layout. In each cross section, plot a 24' wide level road with 4' wide shoulders. The road elevation is 875'. The angle of repose for fill is 1 1/2:1 and 1:1 for cut. Label the road centerline and dimension the road and shoulder widths. The road should slope 0.04 ft./ft. from the centerline to the edge of road. The shoulder slope is 0.06 ft./ft. Label the slopes on your drawing. Draw the cut and fill beginning at the outside edge of the road shoulder. Label the cut and fill with the appropriate symbol and values. Draw the existing grade as a dashed line in the areas of cut and fill. Use the earth sectioning symbol in areas of undisturbed earth. After drawing each cross section, determine the elevation at the intersection of the grade line and cut line. Use these elevations to calculate the earthwork involved between stations 5+00 and 7+00. Use the average end method illustrated in Figure 12-16 to calculate volumes of material in cubic yards and record the values by each cross section.

P12-8 Use the finished drawing from Problem P12-4 to complete this problem. Create three cross sections through the new road and determine the cut and fill. Use the following information for this problem:

- Cut three cross sections perpendicular through the road and cut and fill at the following locations: cross section A, 220' along the road centerline from point A; cross section B, 415' from cross section A, or at the widest area of fill; cross section C, 450' along the road centerline from the PI at point B.
- Locate completed cross sections on separate ANSI C size sheets, one section per sheet.
- The vertical scale of the cross sections is to be the same as the horizontal scale.
- The road surface has a slope of 0.02 ft./ft. from the road centerline.
- The shoulder surface has a slope of 0.06 ft./ft. from the edge of pavement (EOP).
- Exaggerate the road and shoulder surface slope angle on the drawing for clarity.
- The road has the following composition: 12" thick base of gravel (show as dashed line); 6" thick sand-asphalt hot mix (show as solid line); 1 1/4" thick asphaltic-concrete surface (show as thick solid line).
- Draw cross sections with an appropriate scale that allows the drawing, especially the area of cut and fill, to be shown as large as possible on the sheet. Each cross section sheet may have a different scale.
- Label the centerline of the proposed road, bearings and distances, and location points on the road.
- Label the road width, shoulder width, road surface and shoulder surface slopes, and the centerline of the road in all cross sections.
- Label the road composition in all cross sections as local notes or called out on one sheet in general notes, with local note references on each drawing.
- Indicate cut and fill in cross sections with a note and show the angle of repose symbol and values on each side of the road, along the appropriate slope.
- Below all three cross section viewing arrow symbols on the base drawing, place a drawing reference in parentheses. For example, section A-A, if shown on sheet number P12-8-02, should have the label (P12-8-02) below one of the viewing arrows. Place a similar cross-reference label on the cross section drawing just below the section name.
- Use an appropriate graphic pattern to indicate areas of undisturbed earth only. Place patches of this symbol at angular changes of undisturbed earth and several places along slopes.
- Title all cross section drawings HWY. CROSS SECTION.
- Change the title of original map to HIGHWAY CUT AND FILL.
- Begin drawing numbers with P12-8-01 on the HIGHWAY CUT AND FILL drawing and continue in sequence with cross sections.
- Label the sheets as a set, such as 1 of 4, 2 of 4, and so on.
- Submit drawings plotted to scale on ANSI C size sheets, complete with border and title block.

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CHAPTER

13

Detail Drawings

Learning Objectives

After completing this chapter, you will be able to:

- Explain the purpose of detail drawings and views.
- Identify various civil engineering detail drawings.
- Read detail drawings.
- Create detail drawings.

Key Terms

Detail drawing
Detail
Detail view
Detail reference symbol
Typical detail
Speed hump
Pictorial view
Storm sewage
Combined sewerage outlet (CSO)
Domestic sewage
Storm sewer
Catch basin
Manhole
Low impact development (LID)
Low impact development approach (LIDA)
Erosion control
Sanitary sewer
Potable water
Thrust block
Poured-in-place concrete
Precast concrete
Tilt-up concrete
Reinforced concrete
Concrete block
Concrete masonry unit (CMU)
Footing
Wood-frame construction
Light-frame construction

A **detail drawing**, or **detail**, is typically an enlarged view created to describe features not shown on other drawings. Details can be created for any construction feature. Standard details normally specify standards that govern the project, and are used to guide construction. Most civil engineering companies and agencies have large libraries of standard details. This chapter explores the purpose of detail drawings, and describes and provides examples of some of the different types of detail drawings required for civil engineering projects.

Detail Drawing Format

A **detail view** is a drawing view that can be used to display and dimension a portion of another view that has detail that cannot be clearly shown due to the drawing scale or complexity. Detail views are used in all drafting disciplines, though the standards for establishing and presenting detail views vary. Figure 13–1 shows an example of a detail view used to display a small portion of a subdivision plat. A detail view is required in this example to dimension a storm drainage easement on lot 10 that is too small to dimension on the principle plan.

To establish a detail view, an object such as a circle or rectangle is placed around the area in the principle view to be enlarged. A thick phantom line is standard for the boundary object, though some companies and agencies prefer a different line convention, such as the thick long dash triple-dot example shown in Figure 13–1. The boundary object may be broken at a convenient location and an identification letter centered between arrowheads in the break, or a specific note may be used as shown in Figure 13–1. The height of this letter or note is generally 0.24" or 0.25" (6 mm) so it stands out from other text. A detail view of the area is then placed in a convenient location in the field of the drawing. Detail views are generally enlarged to scales such as two, four, or ten times the scale of the principle view. For example, the principle plan view in Figure 13–1 is drawn at a 1" = 40' scale and the detail view is drawn at a 1" = 20' scale, or twice the principle view scale. The view enlargement provides clarity and ease of dimensioning the features. The view identification, and often the scale, is typically placed below the enlarged view, such as DETAIL B. The title text height is generally 0.24" or 0.25" (6 mm).

Cross-Referencing

The detail drawings required in the documentation of a civil engineering project serve the same purpose as detail views, which is to describe features not shown on other views. Details may be shown on one of the plan sheets if they are common features and the subject of a specific plan. If a detail is not a typical construction standard, it may be shown on plan sheets, cross sections, or with other details. Cross-referencing is required to organize and locate views in a set of drawings. A site plan, for example, should contain references to the profiles, cross sections, and details necessary to fully document the project.

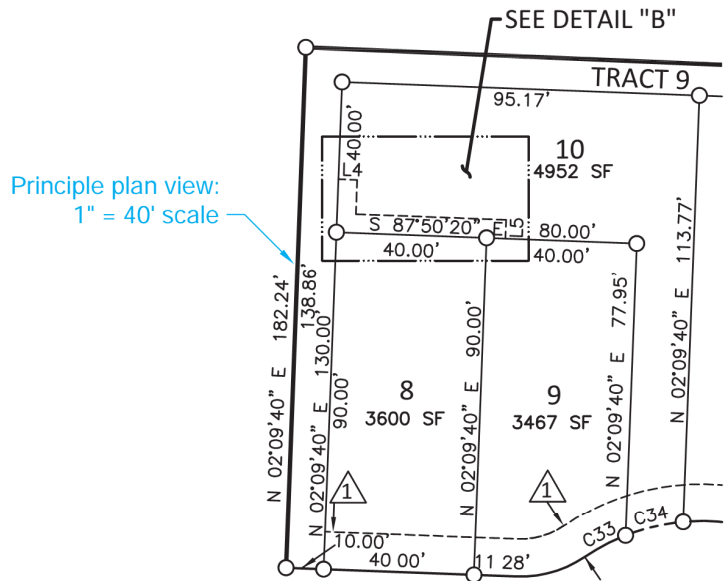
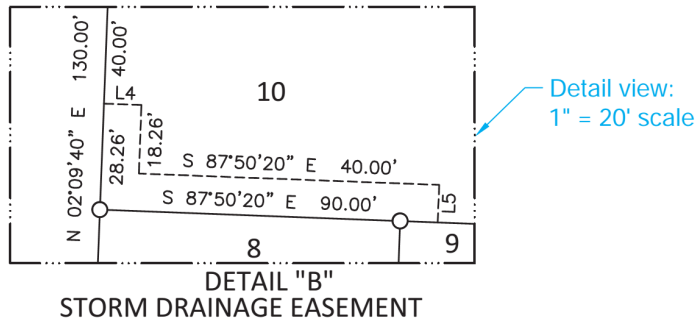


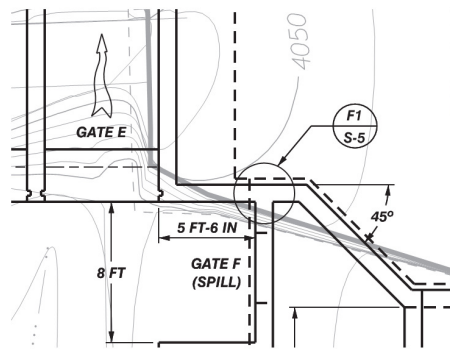
Figure 13-1. The portion of the principle plan view of a subdivision plat requires a detail view in order to dimension the storm drainage easement.

(Courtesy of KPFF Consulting Engineers)

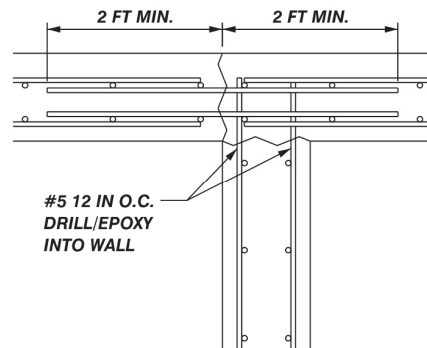
A **detail reference symbol** with cross-reference information is drawn on a view, such as a plan view, to show the location of a detail and help key the plan view to the detail in a set of drawings. Figure 13-2a displays a portion of a site plan. The letter in the top half of the detail reference symbol is the identification for the detail, and the information in the lower half of the symbol indicates the sheet on which the detail is shown. The sheets in a set of drawings for a project are numbered sequentially. To find detail F1 in Figure 13-2a, go to sheet S-5 of the drawing set. Figure 13-2b shows detail F1. In the Figure 13-2 example, the plan view is drawn at a $1" = 10'$ scale and the detail is drawn at a $1/2" = 1'-0"$ scale.

A **typical detail** is common to any location associated with the feature, standard, or code addressed by the detail. Figure 13-3 shows examples of typical details used to indicate the required setbacks for the two types of lots within a proposed subdivision. A detail reference symbol for a typical detail is usually not shown on the referenced drawing. A detail usually has a specified scale, or may be indicated as not to scale (NTS) as shown in Figure 13-3.

Figure 13-2. (a) A portion of a site plan for a concrete irrigation structure removal project. The detail reference symbol identifies the location of a detail F1 on the plan and in the set of drawings. Detail F1 is shown on sheet S-5. (b) This is detail F1, found on sheet 2 and shown on sheet S-5.
(Courtesy of Sage Civil Engineering)



(a)



F1
S-5 **CORNER REINFORCEMENT (PLAN VIEW)**

(b)

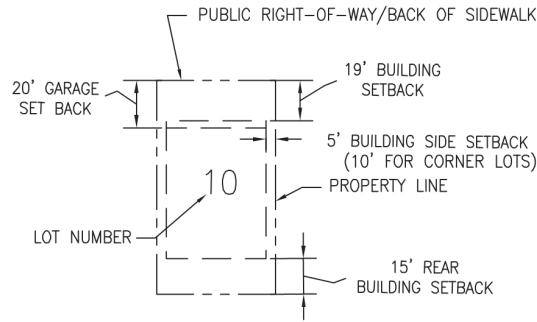
Note: The NCS Uniform Drawing System, Drafting Conventions module addresses standard practices used on drawings, such as drawing orientation, layout, symbols, material indications, line types, dimensions, drawing scale, diagrams, notation, and detail drawing cross-referencing.

Standard Details

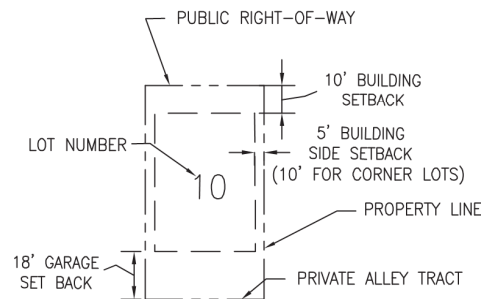
Civil engineering is a broad discipline, and civil engineering detail drawings are used to display a wide variety of information for different types of projects. Structural components and connections, utility layouts, manufactured products used in the construction of a structure, safety features, and environmental compliance requirements are just a few of the different elements of projects shown with detail drawings. A detail is drawn in whatever format and orientation is necessary to describe the feature. Plan (top), elevation (front, side, and rear), profile, cross section, and pictorial views are all used to display details.

The design and construction of land development and civil engineering projects must adhere to a variety of codes and standards. The following material provides different examples of the wide variety of standard detail drawings that are developed and maintained by civil engineering firms, government agencies, and client companies. The

Figure 13-3. Typical plan view details showing the required setbacks beyond which structures cannot be placed on lots throughout a subdivision.
(Courtesy of Otak, Inc.)



FRONT LOADED SINGLE FAMILY
BUILDING SETBACKS (LOTS 16-38)
TYPICAL NTS



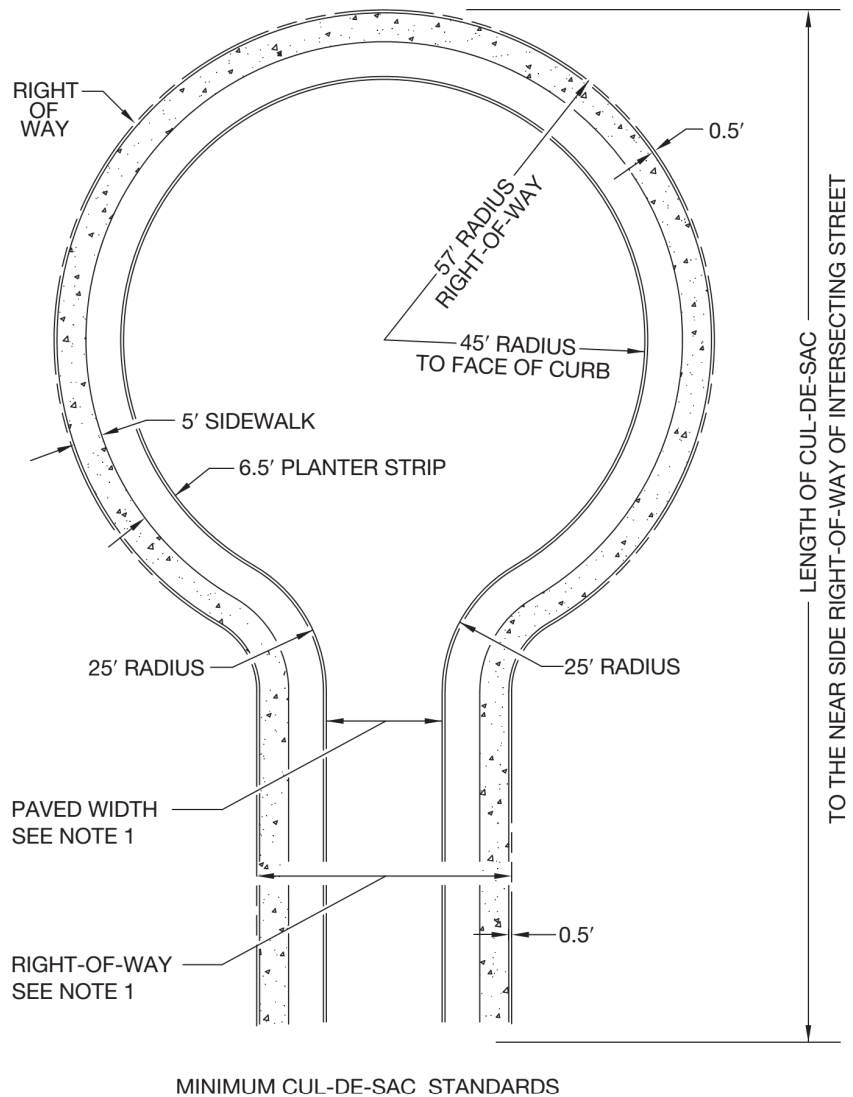
ALLEY LOADED TOWNHOMES
BUILDING SETBACKS (LOTS 1-15)
TYPICAL NTS

detail drawing examples show some of the different types of features for which details are typically provided, and how different civil engineering companies and agencies present detail drawings. The treatment and presentation of the various drawings shown in this chapter varies from one location to another.

Road Details

Road design and construction standards specify the engineering requirements for road and bridge construction and improvements. There are different standard details associated with all aspects of road and street design, construction, and maintenance. Common details for road and street construction projects include various street design features such as curbs, sidewalks, sidewalk ramps, medians, cul-de-sacs, utilities, and signage.

Figure 13-4 displays a plan view detail drawing of a cul-de-sac. Figure 13-5 shows an example of a typical cross section road detail. The cross section is common to any location along a street that includes a planter area between the street and a sidewalk on both sides of the street. Figure 13-6 provides an example of a speed hump detail. A **speed hump** is a mound placed in the road intended to reduce traffic speed and volume. The Figure 13-6 drawing includes



MINIMUM CUL-DE-SAC STANDARDS

NOTES:

1. See *Beaverton Standard Dwg 103* for Local Street right-of-way and paved width standards.
2. A planter strip is required on all Cul-de-sacs.
3. Paved width and planter strip are measured to face of curb.
4. Provide 0.5 feet from right-of-way line to back of sidewalk for maintenance and survey monument protection.
5. Street trees and street lights are required and shall be located within the planter strip.
6. Length of cul-de-sac shall not exceed 200 feet.

Figure 13-4. A plan view detail view that provides minimum standards for a cul-de-sac layout.

(Courtesy of PACE Engineers, Inc.)

a plan view showing speed hump layout, signing and stripping; and cross sections showing the vertical elements of the speed hump installation. Figure 13-7 displays a standard detail of a barricade used to block the end of a street.

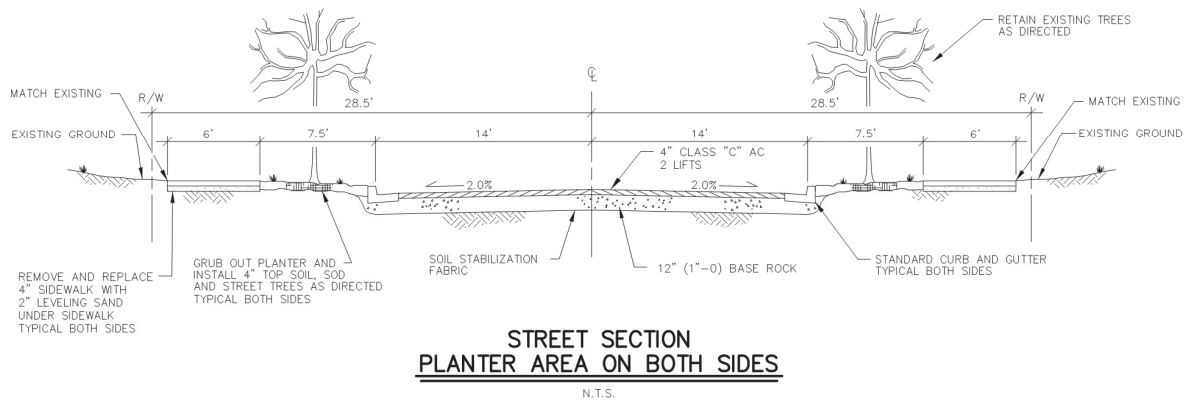


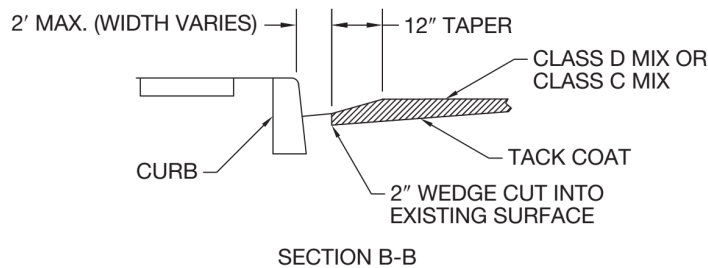
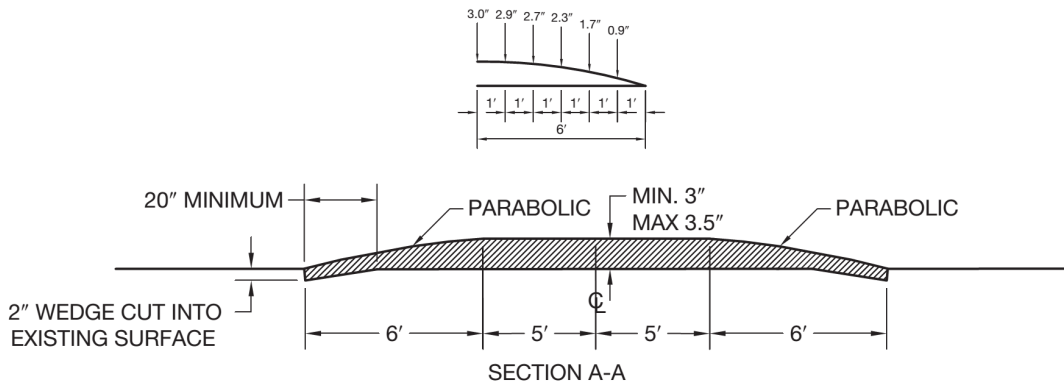
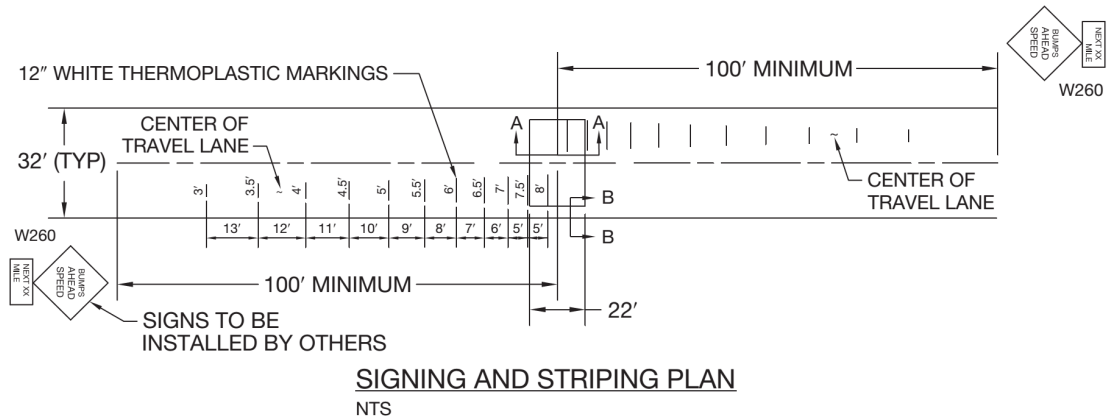
Figure 13-5. A typical cross section common to any location along a street that includes a planter area between the street and the sidewalk on both sides of the street.
(Courtesy of PACE Engineers, Inc.)

Detail drawings are some of the few drawings in a set of drawings sometimes presented in the form of a pictorial view. A **pictorial view** is a view showing an object in three-dimensional (3-D) picture. Figure 13-8 shows examples of pictorial view road details. Figure 13-8a details the requirements for building a residential driveway apron at the intersection of a street. Figure 13-8b specifies how to transition a concrete curb with a gutter to a curb without a gutter.

Storm Sewer Details

Sewage from residential, commercial, and institutional buildings must be disposed of properly according to state Department of Environmental Quality (DEQ) regulations and local building codes. **Storm sewage** is wastewater from rain and groundwater runoff. Storm sewage is processed in a separate storm sewer or, in some cases, with domestic sewage in a system known as a **combined sewerage outlet (CSO)**. **Domestic sewage** is the wastewater from toilets, bathtubs, showers, laundry, and kitchen. A **storm sewer** is a system of underground pipes that carry water runoff from building and land surfaces. Sewer management codes and standards are intended to prevent or reduce adverse effects to the drainage system and water resources of an area. The local sewage district is usually responsible for providing sewage disposal system drawings and specifications.

Storm sewer details focus on storm drains and all required inlets, grating, manholes and access ways, piping, valves, and pump stations. Figure 13-9 shows a standard detail of a curbside storm sewer drain inlet at the edge of a street. A storm sewer drain inlet is a location where storm sewage enters the storm sewer system. A **catch basin**, detailed in Figure 13-10, is a storm sewer inlet designed to collect runoff and trap debris that would otherwise flow into the sewer pipe. Figure 13-11 shows a standard detail of a 72" manhole. A **manhole** is an underground structure used for maintenance access or for making connections to underground utilities and other services, including sewers, telephone, electricity, storm drains, and gas. Figure 13-12 displays a detail drawing of a manhole with storm sewer connections.



NOTES:

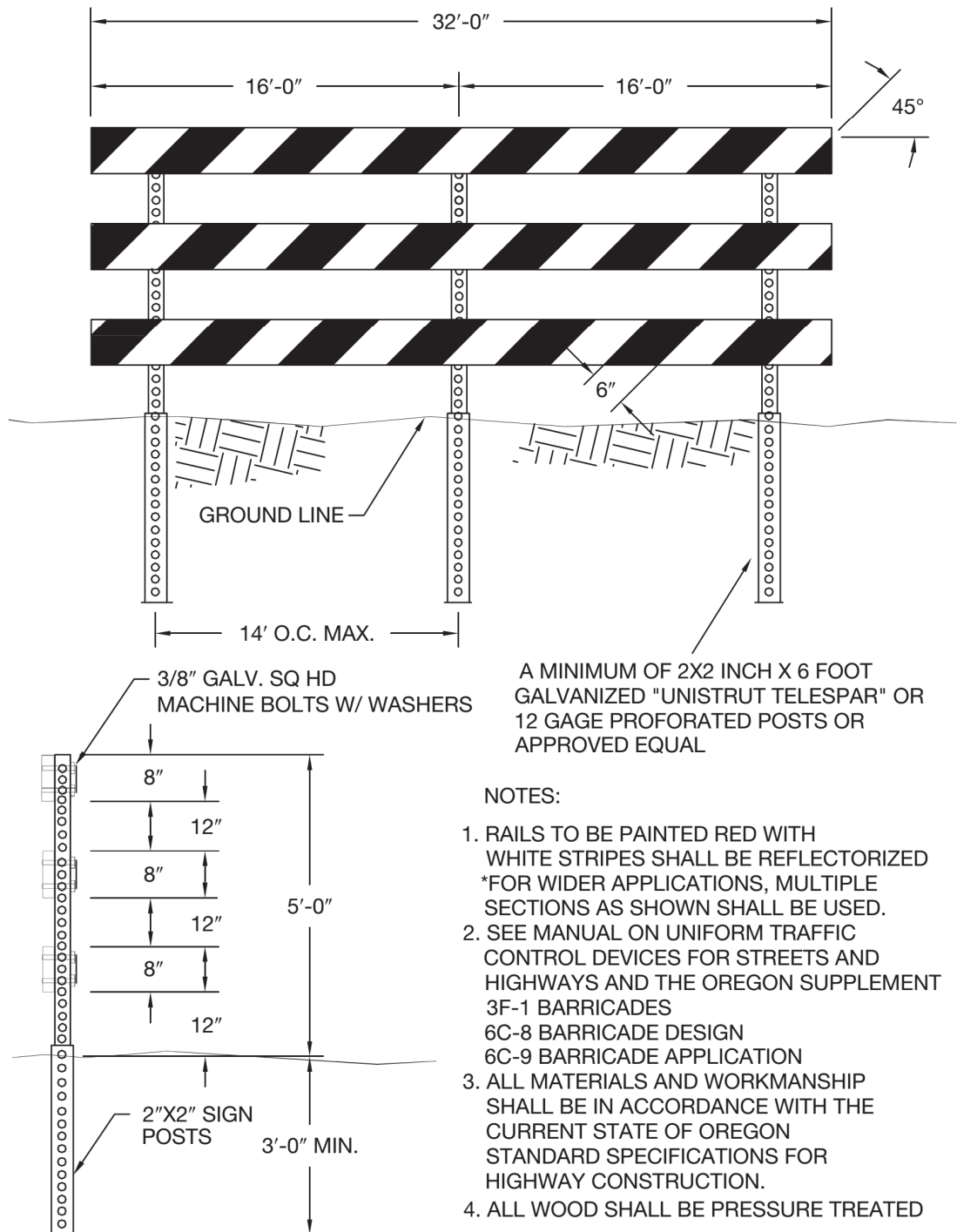
1. SPACING - SPEED HUMPS SHOULD BE PLACED ACCORDING TO THE ENGINEER'S EVALUATION OF THE PHYSICAL STREET SECTION AS WELL AS TRAFFIC OPERATIONS DATA. TYPICALLY, SPEED HUMPS SHOULD BE PLACED BETWEEN 300 AND 600 FEET APART.
2. TOLERANCE - THE TOLERANCE FOR SPEED HUMPS SHOULDN'T VARY BY MORE THAN .5" FROM THE CITY'S TEMPLATE.

22 FT. WIDE SPEED HUMP

N.T.S.

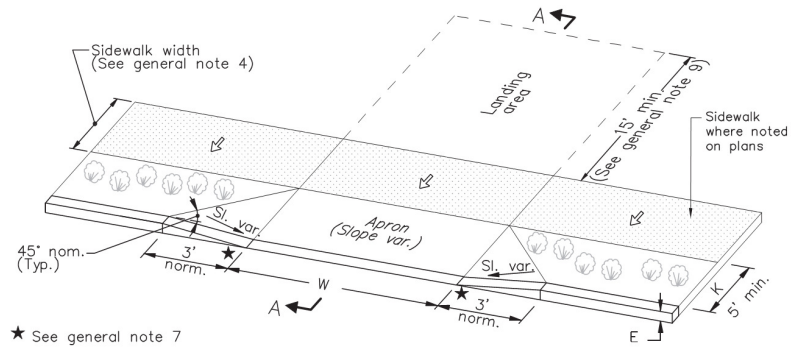
Figure 13-6. A detail drawing of a road speed hump that includes a plan view and two cross sections.

(Courtesy of PACE Engineers, Inc.)



STREET BARRICADE TYPE III

Figure 13-7. A standard detail of a barricade with a front and side view.
(Courtesy of the City of Forest Grove, Oregon)



(Refer to Oregon Standard Drawing RD740 for SECTION A-A and all general notes referenced in this drawing)

2 RESIDENTIAL CONCRETE DRIVEWAY APRON

SCALE: NTS

(a)

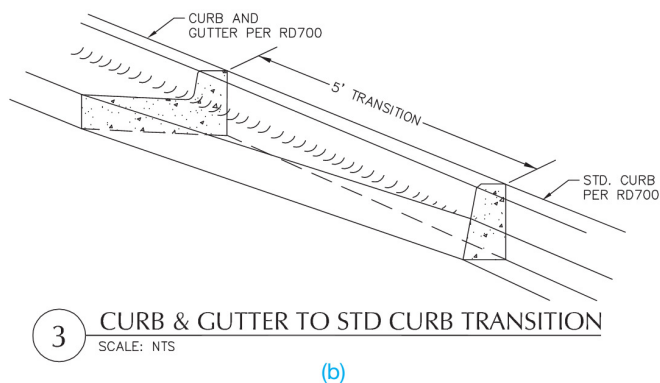


Figure 13-8. Details drawn as pictorial views. (a) A detail showing the construction of a residential driveway apron at the intersection of a street. (b) A detail showing the transition between a concrete curb with a gutter to a curb without a gutter.

(Courtesy of KPFF Consulting Engineers)

Water Quality Details

There are different methods for managing storm water runoff in addition to conventional storm sewer systems. **Low impact development (LID)** or **low impact development approach (LIDA)** are common terms used to describe techniques for managing storm water using systems modeled after nature, such as rain gardens, vegetated swales, porous pavement, and storm water planters. Standard detail drawings provide the detailed specifications required to implement LID practices in the design and construction of a project. Figure 13-13 shows a common example of a LIDA, a storm water planter intended to collect and naturally filter storm water runoff. Figure 13-14 displays another storm water planter. Compare Figure 13-13 and Figure 13-14 to see how two different civil engineering firms approach the drafting of a similar feature.

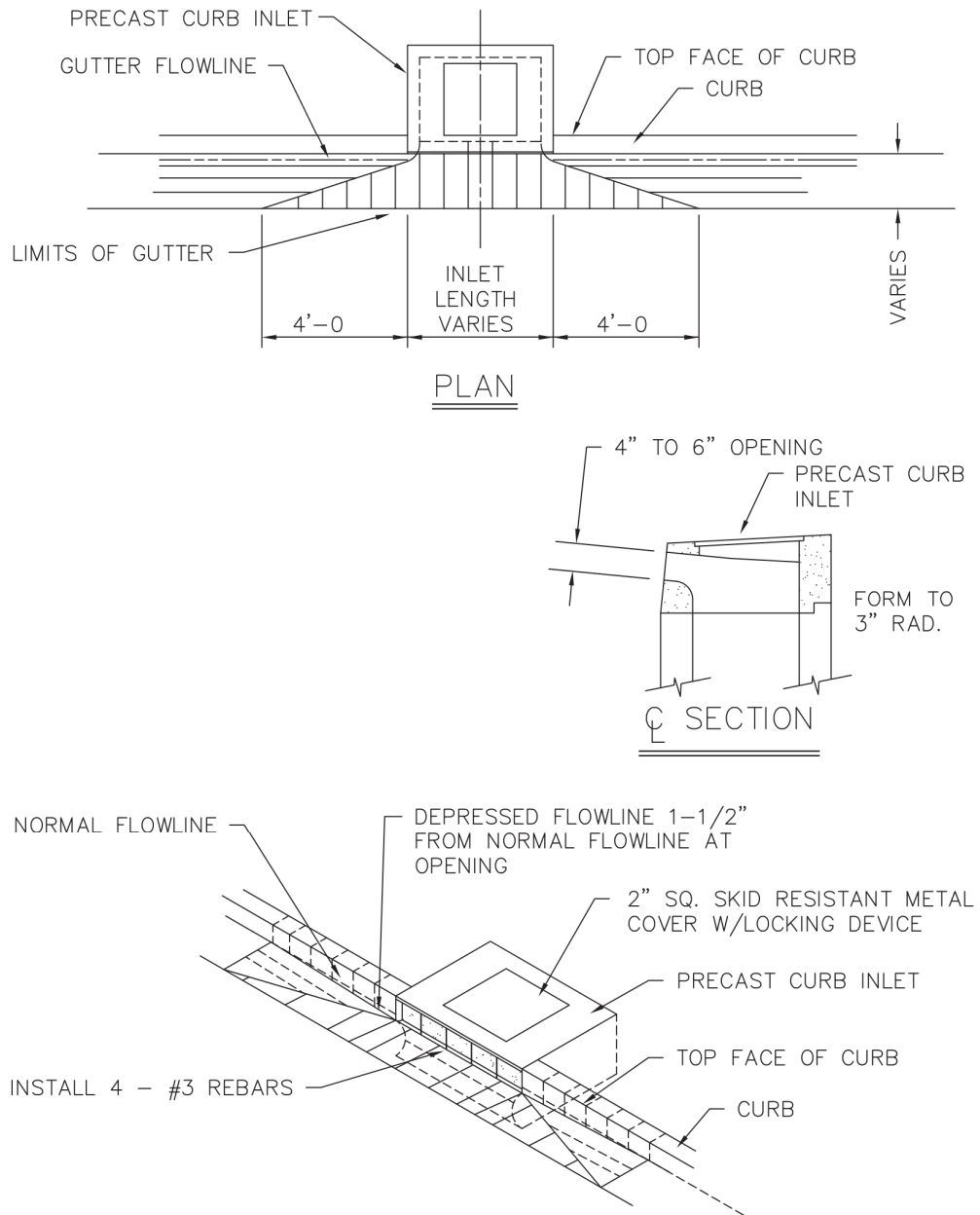


Figure 13-9. A standard detail with a plan, section, and pictorial view of a storm sewer drain inlet.
(Courtesy of PACE Engineers, Inc.)

Erosion control is another example of a system intended to reduce adverse effects to the drainage system and water resources of an area. **Erosion control** is a practice designed to prevent or control wind or water erosion during land use, development, and construction activities. Figure 13-15 shows a detail drawing of a common example of an erosion control system, a silt fence designed to block sediment. Figure 13-16 displays a detail of an erosion protection method used at a storm sewer drain inlet.

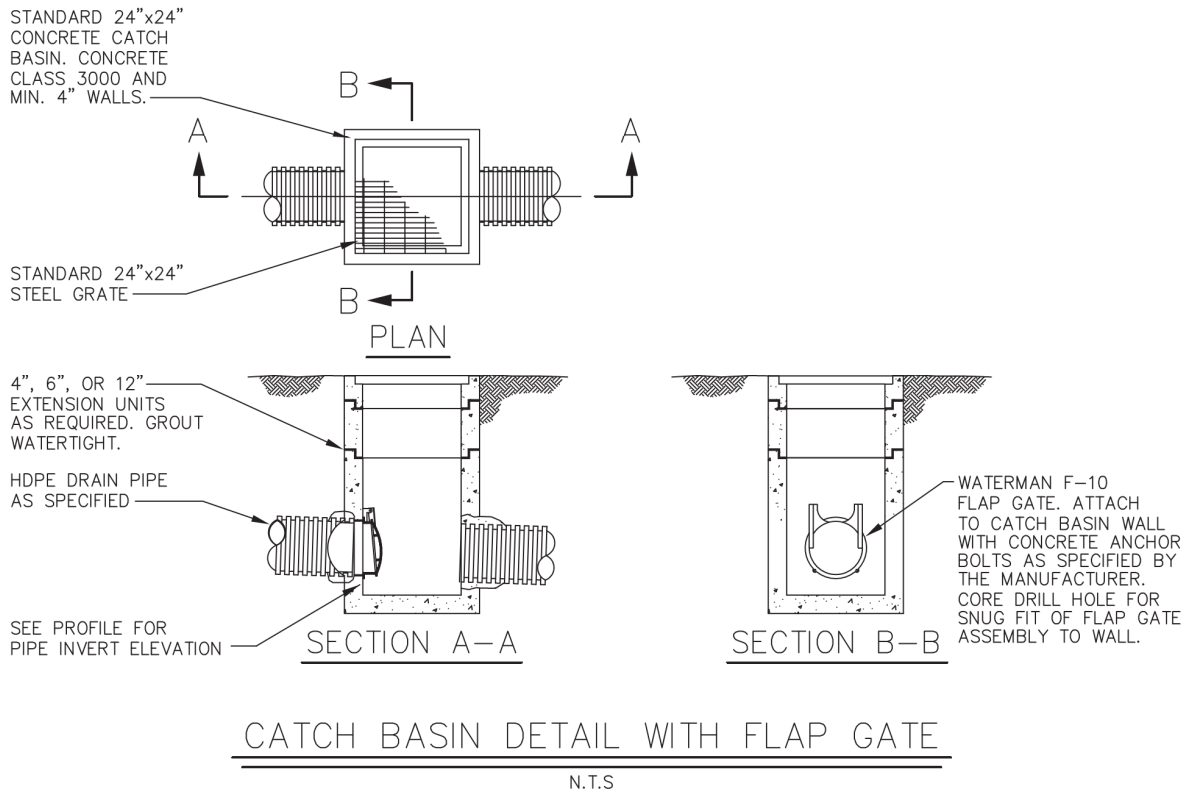


Figure 13-10. A plan and two section views of a catch basin.
(Courtesy of PACE Engineers, Inc.)

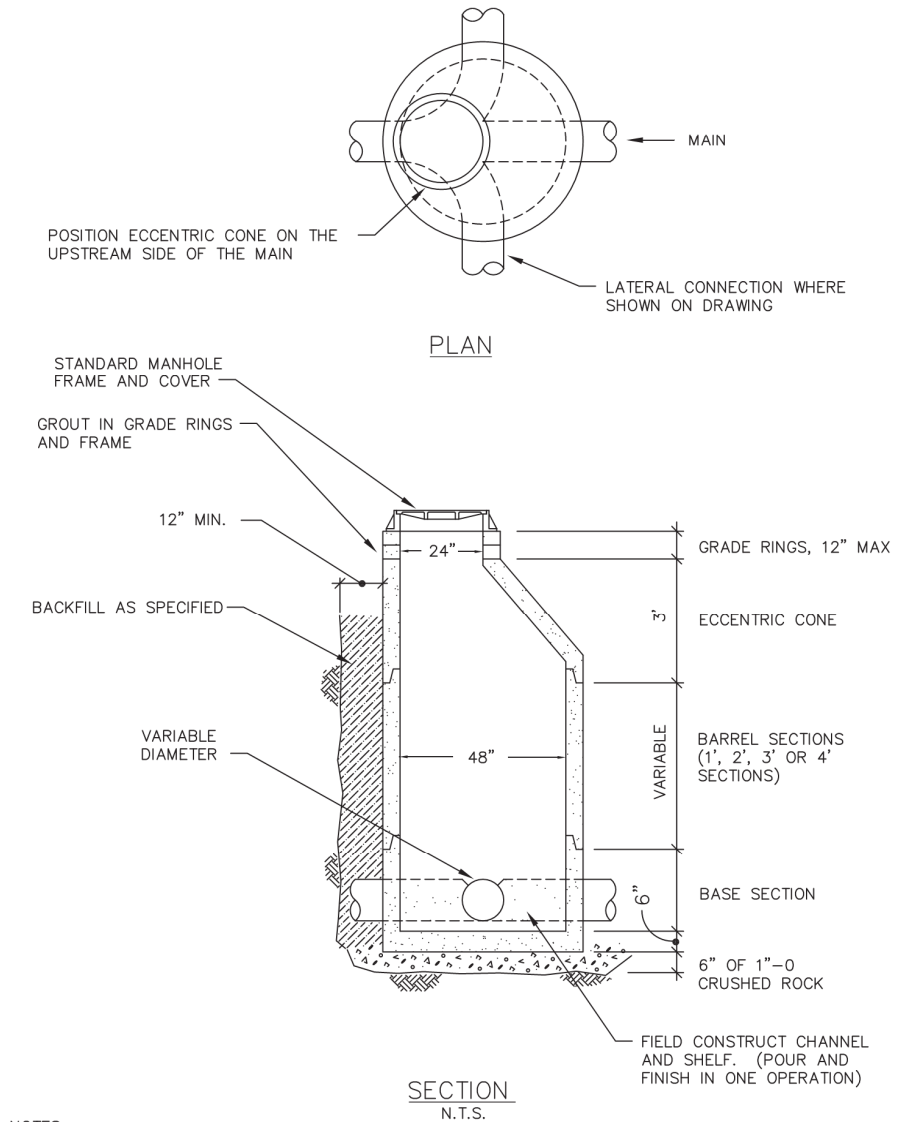
Domestic Sewer Details

Domestic sewer details provide much of the information necessary to design and build the domestic sewage system for a project. In locations where sanitary, or public, sewers are available, details show elements of the design and installation such as the connection of a sanitary service line to the main sewer (see Figure 13-17). A **sanitary sewer** is a system of underground pipes that transports domestic sewage to a treatment plant where the wastewater is cleaned and discharged. Figure 13-18 displays a sanitary sewer catch basin.

Details are also necessary when a septic tank or cesspool is used as the domestic sewage system for a project. Chapter 9 explains the basic design and function of septic tank and cesspool methods of sewage disposal. Figure 13-19 shows a detail of a septic tank. Figure 13-20 displays a detail of a standard septic system cleanout. Figure 13-21 shows a detail of the typical bedding and backfill for septic system piping.

Water Details

Water details are drawn for any kind of water system needs, such as potable water; utility water, or non-potable water; and fire sprinkler water. **Potable water** is water that is safe to drink. Water details



NOTES:

1. MANHOLE BASES, BARREL SECTIONS, ECCENTRIC CONES AND GRADE RINGS SHALL BE CONSTRUCTED OF PRECAST REINFORCED CONCRETE, CONFORMING TO ASTM C478.
2. 48" MANHOLE DETAILS ARE FOR PIPES 30" OR SMALLER. IF LARGER MANHOLES ARE REQUIRED, THEY WILL BE SPECIFIED IN THE DRAWINGS.
3. NO LADDER ASSEMBLIES.

Figure 13-12. A standard detail with a plan and section view of a manhole with storm sewer connections.

(Courtesy of PACE Engineers, Inc.)

bearing areas for thrust blocks at fittings. Figure 13-23 displays a standard detail used to guide the installation of a fire hydrant and valve box. Figure 13-24 shows a standard detail of a fire hydrant valve box. Figure 13-25 shows a standard detail of a water meter that measures the volume of water delivered to a property.

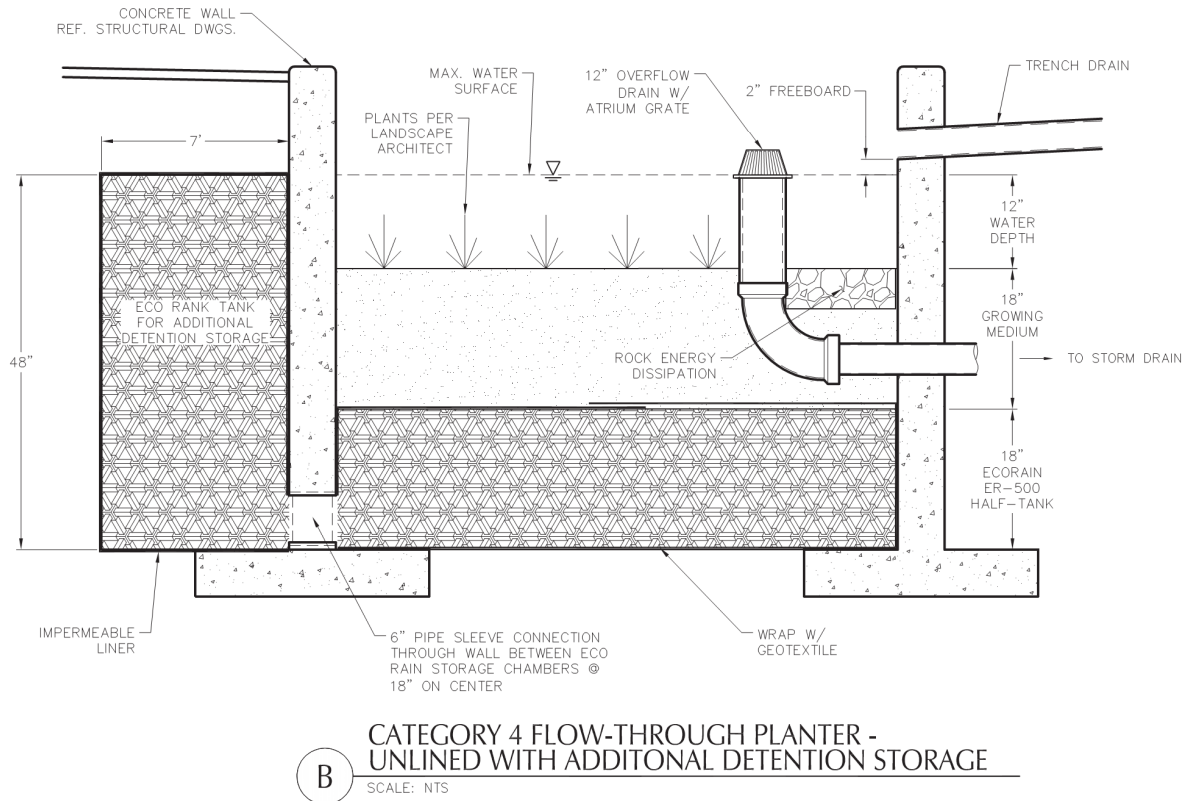


Figure 13-13. A section view showing the construction of a low impact development approach (LIDA) storm water pollution control planter.
(Courtesy of KPFF Consulting Engineers)

Piping Details

Piping details can include pipe, fittings, valves, pumps, and related structural components for any civil engineering project or discipline for which piping is required. The sewer and water systems previously described are examples of projects that required piping details. Figure 13-26 shows a standard detail of a floor-mounted stand intended to support piping from below. Figure 13-27 displays a standard detail of a blow-off assembly used to drain the pipeline and remove sediments that accumulate in low areas of the pipeline. Figure 13-28 displays a standard detail of an air release valve assembly incorporated into a water main line to release air pockets that collect at high points of a pressured pipeline.

Structural Details

Structural engineering drawings and detail drawings show the results of structural designing, and are required for the construction of all types of structures, from residential and commercial buildings to bridges and other road and highway structures. Structural engineering details are included in a set of working drawings for a wide variety

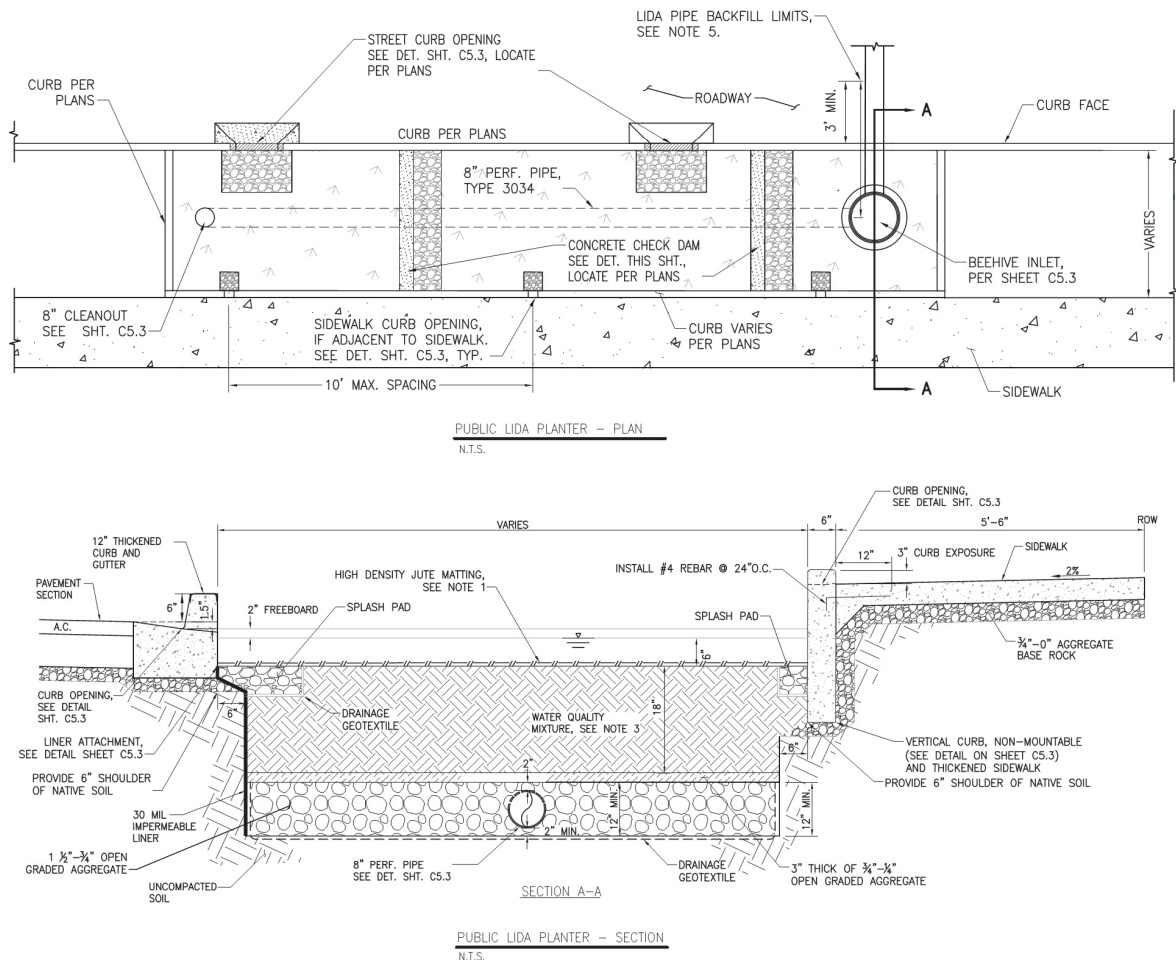
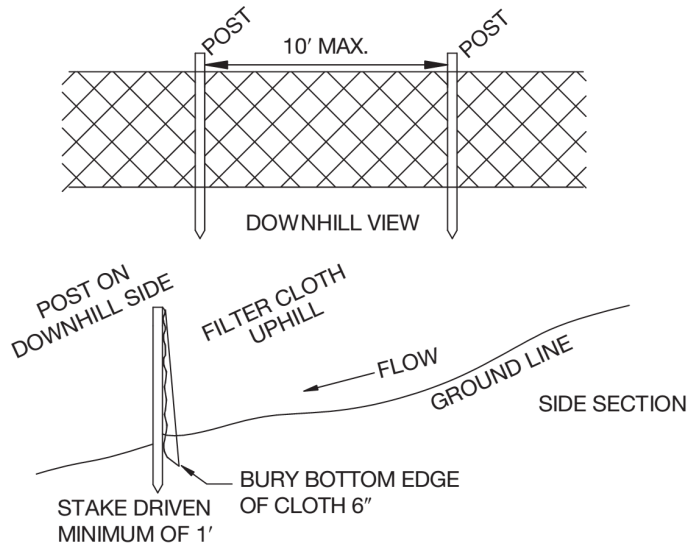


Figure 13-14. A plan and section view showing the construction of another LIDA storm water pollution control planter.
(Courtesy of Otak, Inc.)

of civil engineering projects. Different types of construction details relate directly to the materials to be used, the location where the construction takes place, the type of structure to be built, and engineering practices. Common examples of construction materials presented in structural details are concrete, concrete block, wood, and steel. Structural details often focus on the structural connections in a project, and display the relationship between connected structural members.

Methods of concrete construction include poured-in-place, precast, and tilt-up concrete. **Poured-in-place concrete** construction is the method of pouring unhardened concrete into forms built at the construction site according to the specified size, shape, and location of foundations, floors, walls, columns, beams, and other members. Figure 13-29 shows a standard detail of poured-in-place concrete construction at the transition between a pedestrian walkway and vehicle parking area. **Precast concrete** construction involves forming concrete components off-site at a fabrication plant and transporting the components to the construction site for assembly. **Tilt-up**



SILT FENCE DETAIL

NOT TO SCALE

Figure 13-15. A front elevation and section view of a silt fence erosion control system.

(Courtesy of Chief Architect Software)

concrete is a precast concrete method using formed wall panels that are lifted, or tilted, into place. Concrete poured around steel bars called rebar, or other steel reinforcement placed in the forms is known as **reinforced concrete** (see Figure 13-30).

A **concrete block**, also known as a **concrete masonry unit (CMU)**, is a rectangular masonry construction unit. Concrete block is a durable and cost-effective material. Concrete block construction is

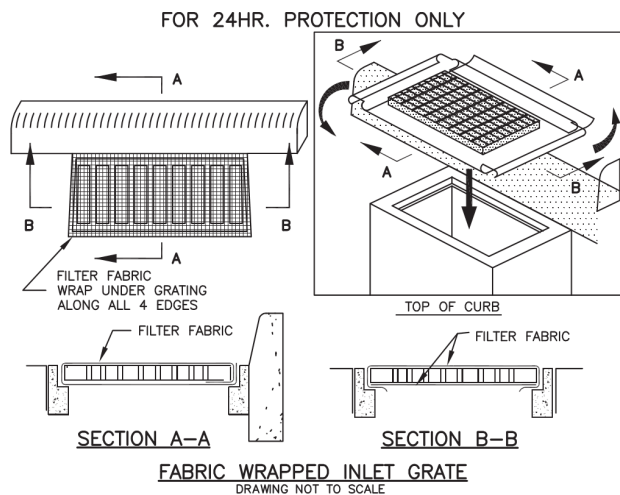


Figure 13-16. Plan, section, and pictorial views of a fabric wrapped inlet grate erosion protection method.

(© City of Portland, courtesy Bureau of Environmental Services)

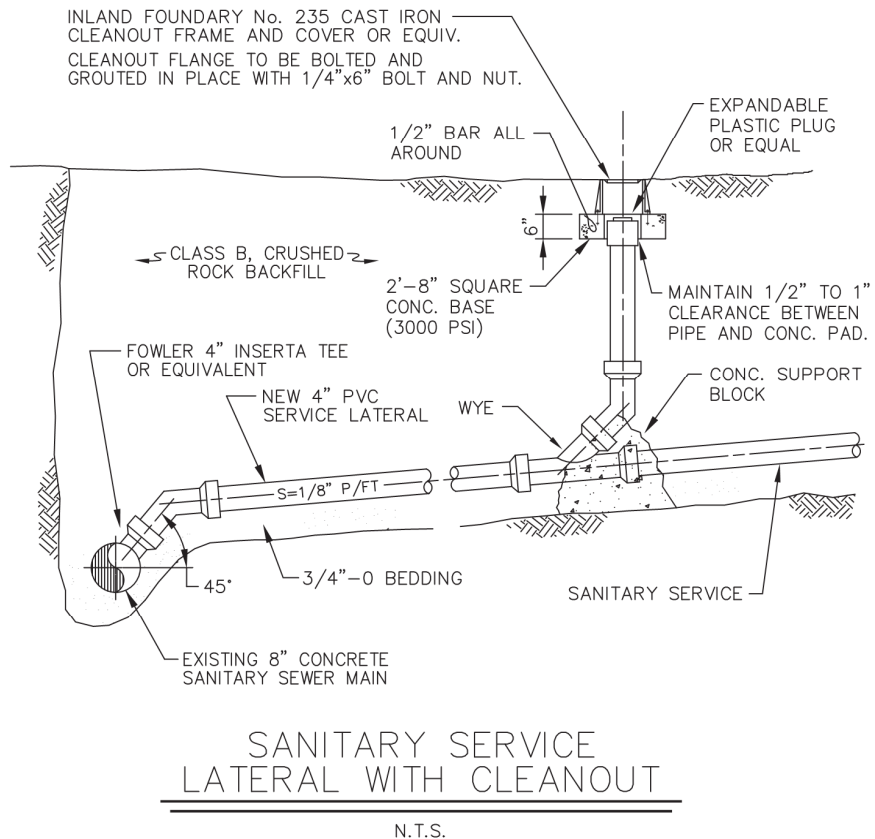


Figure 13-17. A section view detailing a sanitary sewer cleanout with lateral connection to the main sewer.
(Courtesy of PACE Engineers, Inc.)

common for residential foundations, some aboveground residential applications, and commercial wall systems. Figure 13-31 shows a detail of a CMU wall footing. A **footing** is the lowest member of the foundation system used to spread the loads of the structure across supporting soil.

Wood construction includes wood-frame, heavy timber, and laminated beam construction. **Wood-frame construction**, also known as **light-frame construction**, uses dimensional lumber nailed together to form a supporting framework covered with a variety of surfacing materials. Figure 13-32 shows a partial cross section through the exterior wall of a wood-frame building. A typical wall section details the wall construction materials of a specific structure.

Steel details most often illustrate the manner in which steel members are connected and anchored to other steel, concrete, masonry, and wood components. Steel construction includes a wide variety of fasteners, such as bolts, nuts, rebar, rivets, and welds. A good knowledge of welding symbols is beneficial. A company that deals with structural steel likely maintains a symbol library of welding symbols. Figure 13-33 displays a detail of a structural steel beam to column connection.

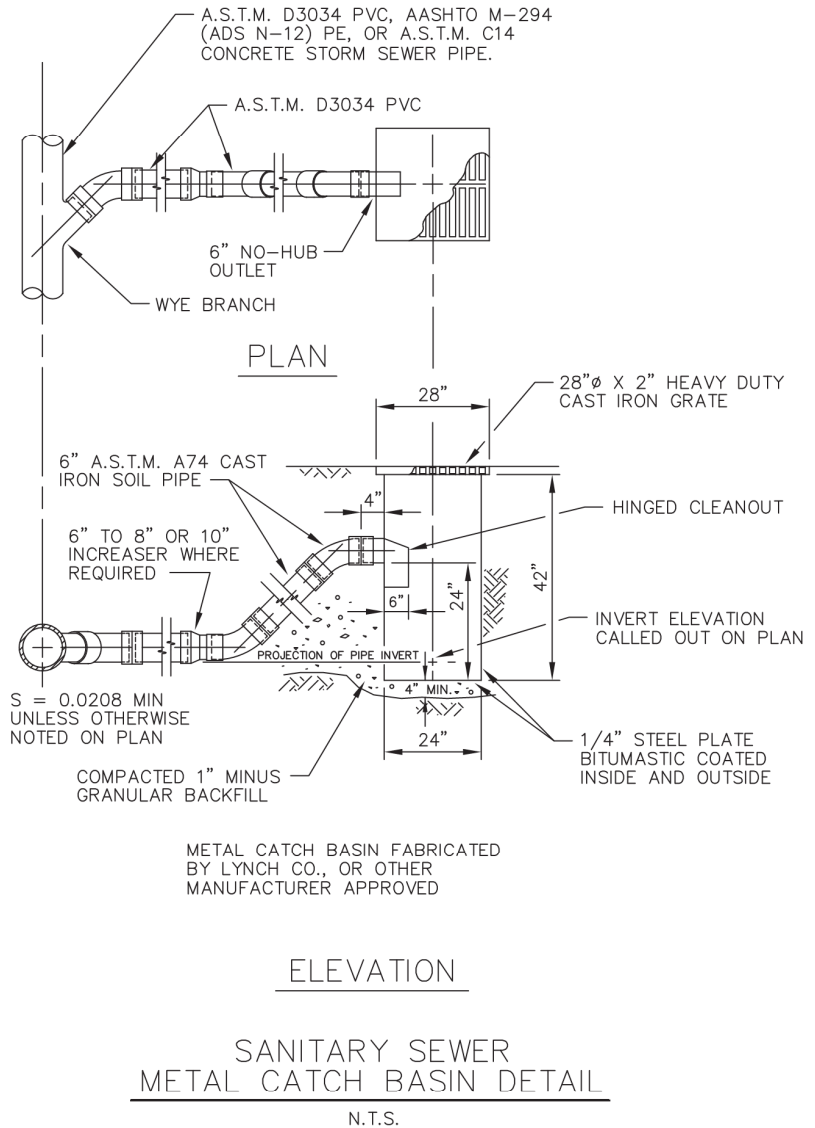
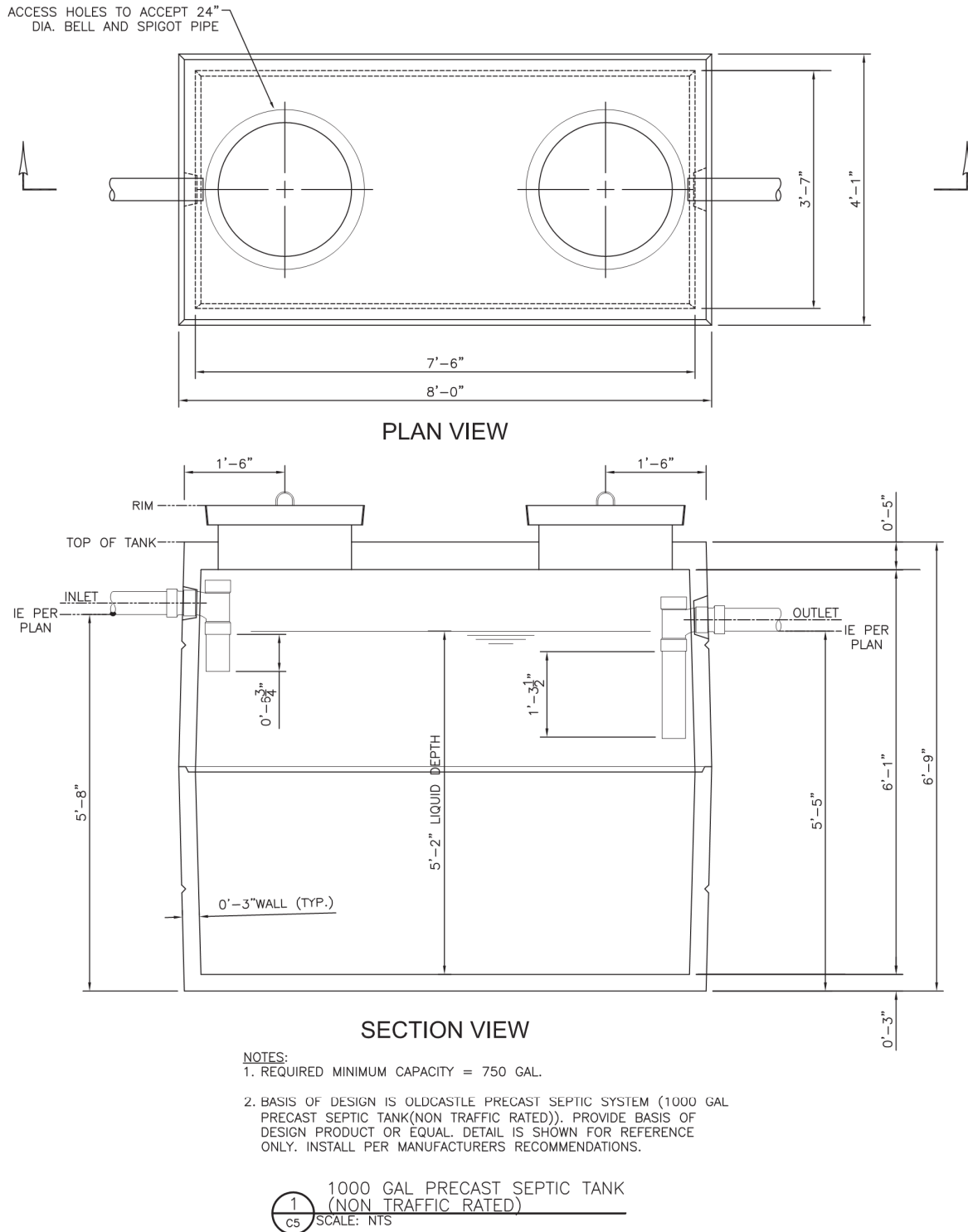


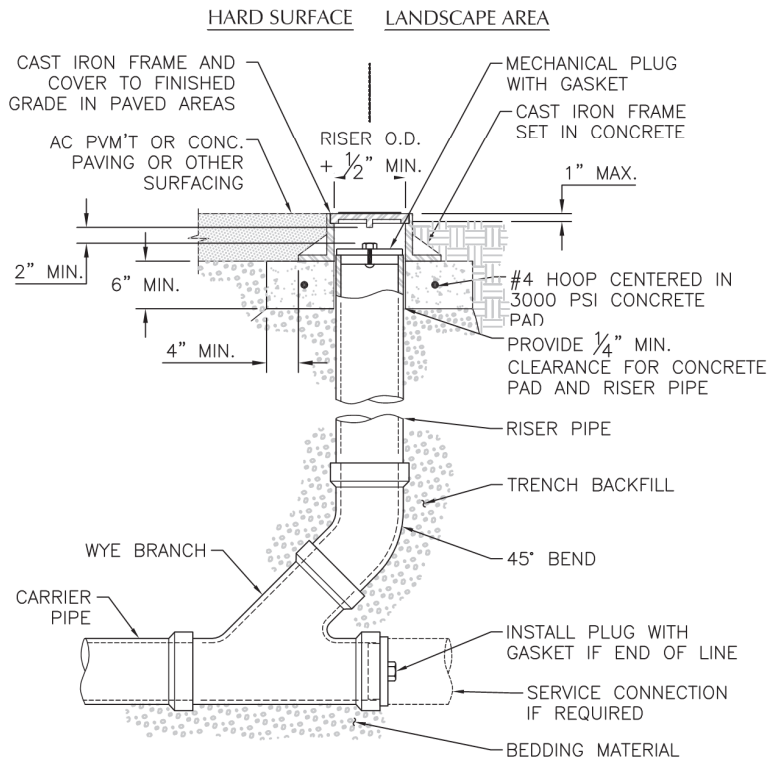
Figure 13-18. A plan and section view detailing a metal catch basin for a sanitary sewer line.

(Courtesy of PACE Engineers, Inc.)

Other Examples of Site Details

Each civil engineering project requires its own unique detail drawings and standard details. The following provides some additional examples of the many different types of detail drawings required for civil engineering projects. Figure 13-34 shows a detail defining the construction of a rock retaining wall. Figure 13-35 shows a standard detail describing how to protect trees from damage during a construction project. Figure 13-36 displays a detail of the construction of stream step pools for a stream restoration project. Figure 13-37 shows a detail of a portion of handrail associated with a concrete irrigation structure removal project.



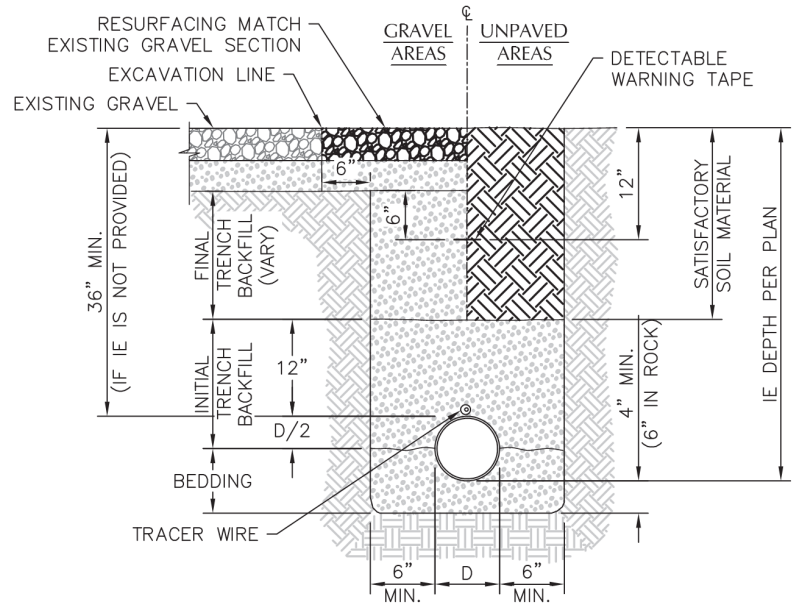


NOTES:

1. CAST IRON FRAME AND COVER SHALL MEET H-20 LOAD REQUIREMENT.
2. FOR CARRIER PIPE SIZE 6"Ø AND LESS, PROVIDE RISER PIPE SIZE TO MATCH CARRIER PIPE.
3. RISER PIPE MATERIAL TO MATCH CARRIER PIPE MATERIAL.

2
STANDARD CLEANOUT (COTG)
 C5 SCALE: NTS

Figure 13-20. A section view of a standard septic system cleanout.
(Courtesy of KPFF Consulting Engineers)



3 TYPICAL PIPE BEDDING AND BACKFILL
C5 SCALE: NTS

Figure 13-21. A section view of the typical bedding and backfill for septic system piping.
(Courtesy of KPFF Consulting Engineers)

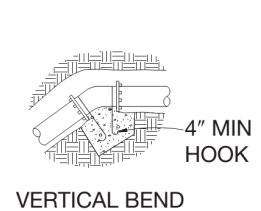
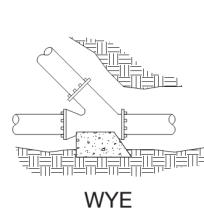
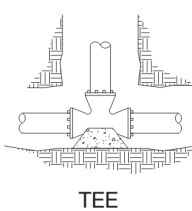
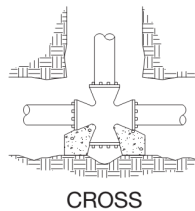
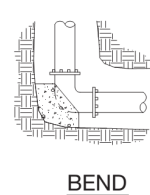
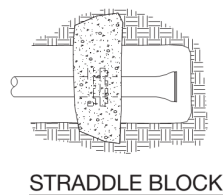
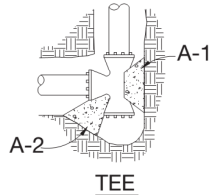
(HORIZONTAL) BEARING AREA OF THRUST BLOCKS IN SQUARE FEET									(VERTICAL) VOLUME OF THRUST BLOCK IN CUBIC YARDS			
FITTING SIZE	TEE, WYE, DEAD END AND HYDRANT	STRADDLE BLOCK	90 BEND PLUGGED CROSS	TEE PLUGGED ON RUN		45 BEND	22-1/2 BEND	11-1/4 BEND	90 BEND	45 BEND	22-1/2 BEND	11-1/4 BEND
				A-1	A-2							
4	1.0	1.6	1.4	1.9	1.4	1.0	---	---	---	---	---	---
6	2.1	3.7	3.0	4.3	3.0	1.6	1.0	---	1.3	---	---	---
8	3.8	6.5	5.3	7.6	5.4	2.9	1.5	1.0	2.3	1.1	---	---
10	5.9	10.2	8.4	11.8	8.4	4.6	2.4	1.2	3.7	1.8	---	---
12	8.5	14.7	12.0	17.0	12.0	6.6	3.4	1.7	5.5	2.8	1.2	---
14	11.5	---	16.3	23.0	16.3	8.9	4.6	2.3	7.6	3.9	1.7	---
16	15.0	26.1	21.3	30.0	21.3	11.6	6.0	3.0	9.9	5.1	2.3	0.9
18	19.0	---	27.0	38.0	27.0	14.6	7.6	3.8	---	---	---	---
20	23.5	40.8	33.3	47.0	33.3	18.1	9.4	4.7	---	---	---	---
24	34.0	58.8	48.0	68.0	48.0	26.2	13.6	6.8	---	---	---	---

NOTES:

- ABOVE BEARING AREAS BASED ON TEST PRESSURE OF 150 PSI AND AN ALLOWABLE SOIL BEARING STRESS OF 2000 POUNDS PER SQUARE FOOT. TO COMPUTE BEARING AREAS FOR DIFFERENT TEST PRESSURES AND SOIL BEARING STRESSES, USE THE FOLLOWING EQUATION:

$$\text{BEARING AREA} = (\text{TEST PRESSURE} / 150) \times (2000 / \text{SOIL BEARING STRESS}) \times (\text{TABLE VALUE})$$
- ABOVE VOLUMES BASED ON TEST PRESSURE OF 150 PSI AND THE WEIGHT OF CONCRETE = 4050 POUNDS PER CUBIC YARD. TO COMPUTE FOR DIFFERENT TEST PRESSURES, USE THE FOLLOWING EQUATION:

$$\text{VOLUME} = (\text{TEST PRESSURE} / 150) \times (\text{TABLE VALUE})$$



RODS FOR VERTICAL BENDS		
FITTING SIZE	ROD SIZE	EMBEDMENT
12" AND LESS	#6	30"
14"-16"	#8	36"

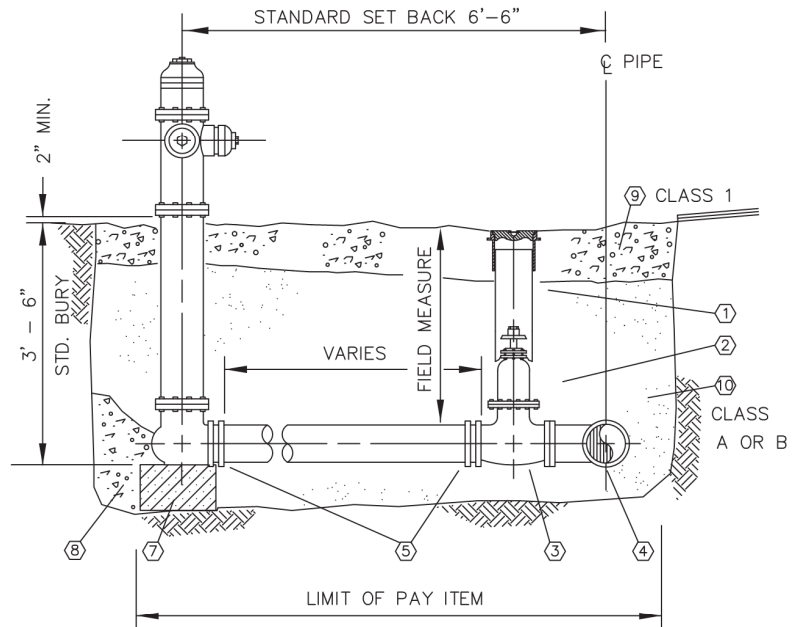
NOTES:

- CONCRETE BLOCKING TO BE POURED AGAINST UNDISTURBED EARTH.
- ALL CONCRETE TO BE CLASS 3000 MINIMUM.
- INSTALL ISOLATION MATERIAL BETWEEN PIPE AND/OR FITTINGS BEFORE POURING CONCRETE BLOCKING.
- CONCRETE SHALL BE KEPT CLEAR OF ALL JOINTS AND ACCESSORIES.
- TIE RODS SHALL BE DEFORMED GALVANIZED COLD ROLLED STEEL, 60,000 PSI TENSILE STRENGTH.

THRUST BLOCK DETAILS

Figure 13-22. Standard concrete thrust block details. The table provides the bearing areas for thrust blocks at fittings.

(Courtesy of the City of Forest Grove, Oregon)



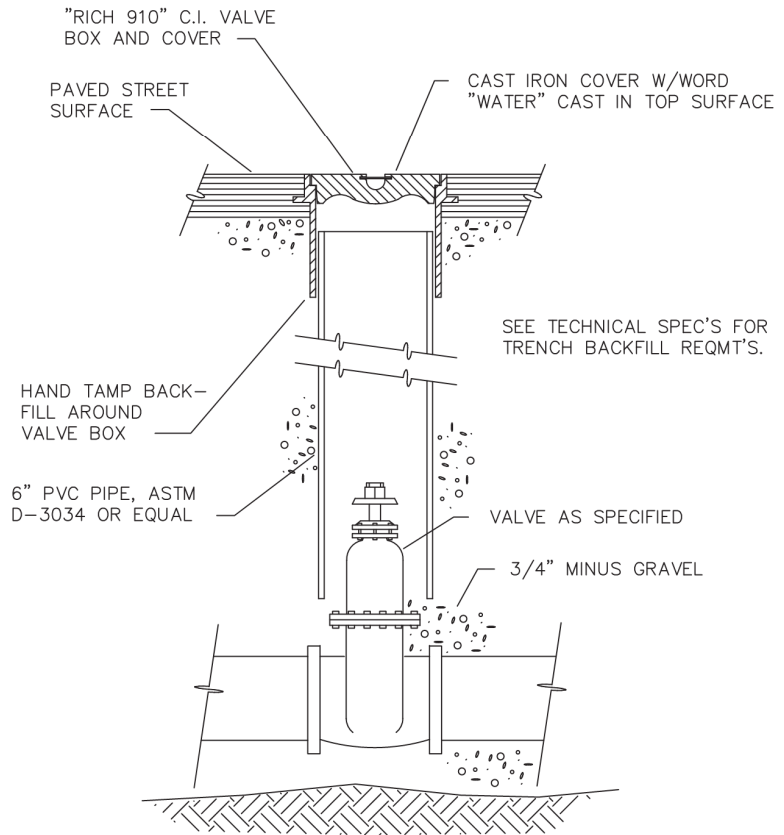
- | | |
|---|---|
| ① VALVE BOX AND LID | ⑦ 12" SQ. X 3" THICK CONC. BLOCK. |
| ② 2 C.F. CRUSHED ROCK UNDER VALVE BOX. | ⑧ 1/2 C.Y. OF 1 1/2" GRAVEL. |
| ③ 6" FLG. X M.J. GATE VALVE | ⑨ SEE TECHNICAL SPECIFICATIONS FOR <u>SURFACE RESTORATION</u> . |
| ④ 6" M.J. X FLG. TEE | ⑩ SEE TECHNICAL SPECIFICATIONS FOR <u>BEDDING AND TRENCH BACKFILL</u> REQUIREMENTS. |
| ⑤ 6" D.I. GROOVED HOLDING SPOOL | |
| ⑥ ALTERNATIVE BLOCKING, TIES, SHACKLES, ETC. SUBJECT TO APPROVAL OF ENGINEER. | |

STANDARD FIRE HYDRANT DETAIL

NOT TO SCALE

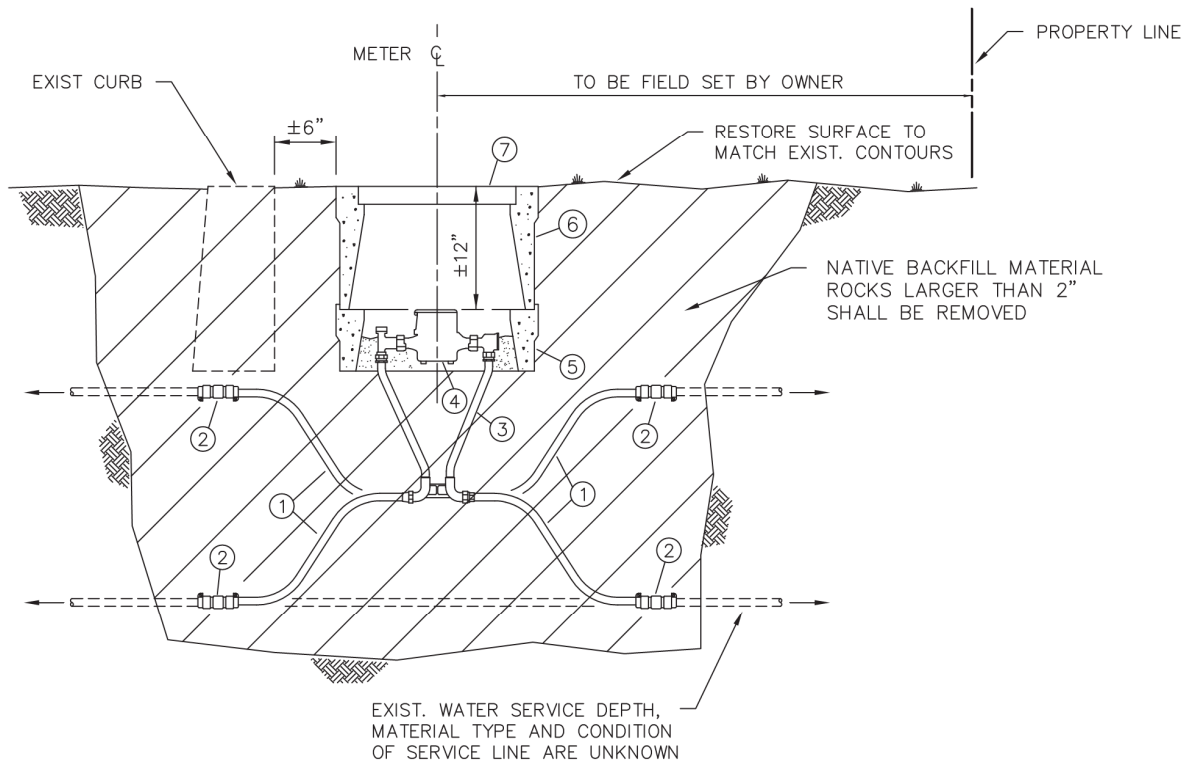
Figure 13-23. A section view of a standard fire hydrant and valve box installation.

(Courtesy of PACE Engineers, Inc.)



SECTION — TYP. VALVE BOX DETAIL
N.T.S.

Figure 13-24. A section view of a standard fire hydrant valve box.
(Courtesy of PACE Engineers, Inc.)



MATERIAL LIST

- ① 3/4" COPPER PIPE TAIL – TWO REQ'D PER INSTALLATION
- ② TRANSITION COUPLINGS/PACK JOINT OR APPROVED EQUAL – TWO REQ'D PER INSTALLATION
- ③ COPPERSETTER, 15" HIGH (AS SPECIFIED)
- ④ 5/8" X 3/4" METER (SUPPLIED BY OWNER)
- ⑤ 8" METER BOX EXTENSION
- ⑥ BROOK 36 SERIES METER BOX (AS SPECIFIED)
- ⑦ METER BOX LID – SEE SPECIFICATIONS FOR TYPE

METER INSTALLATION DETAIL

N.T.S.

Figure 13–25. A section view of a standard water meter installation.
(Courtesy of PACE Engineers, Inc.)

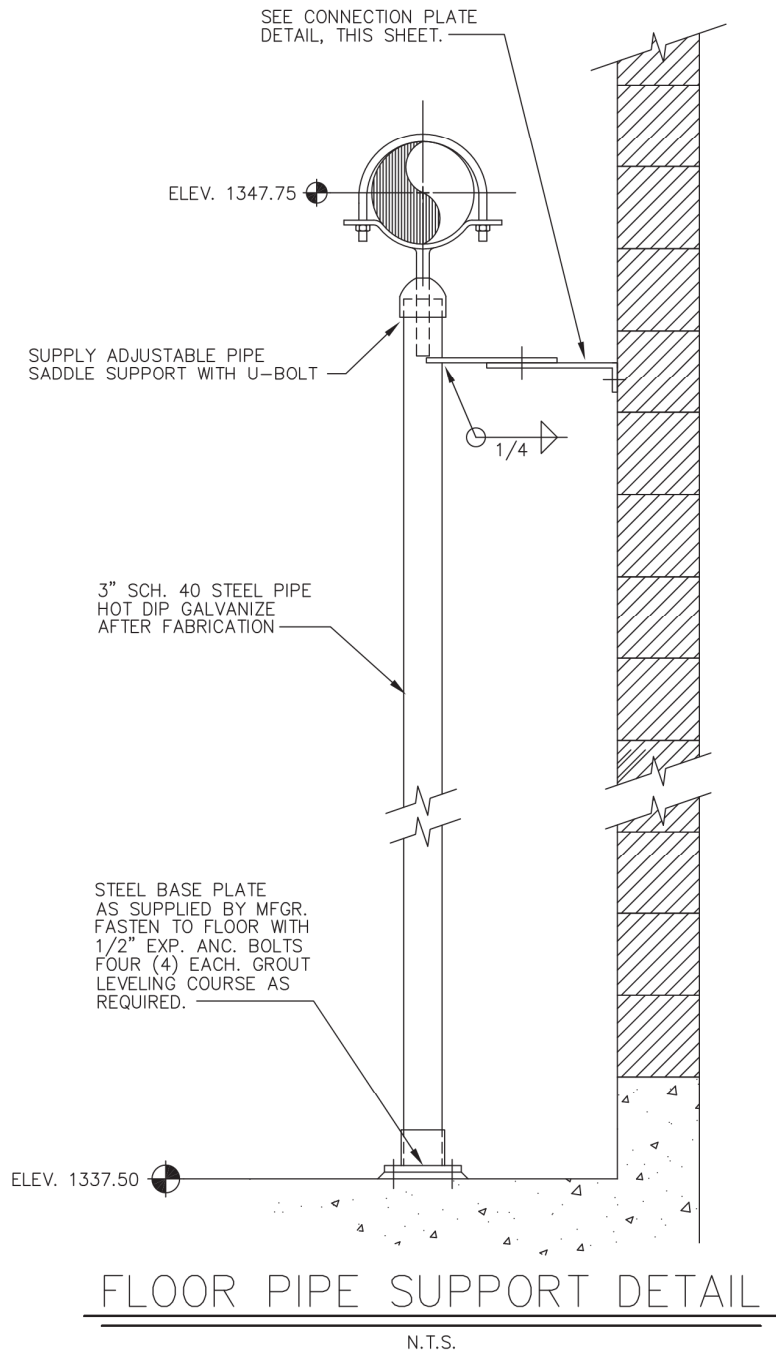


Figure 13-26. A section or elevation view of a floor-mounted piping support.
(Courtesy of PACE Engineers, Inc.)

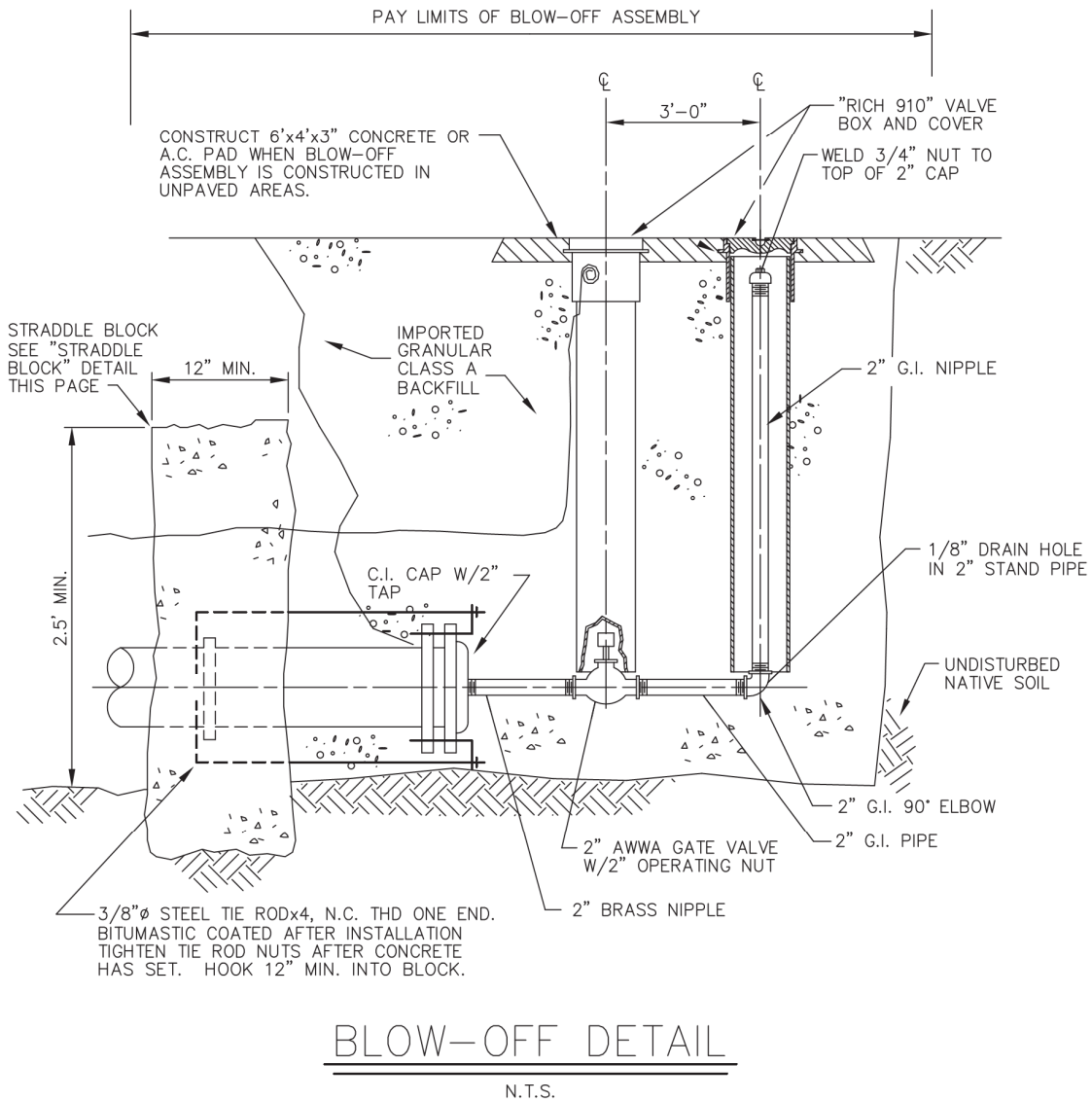
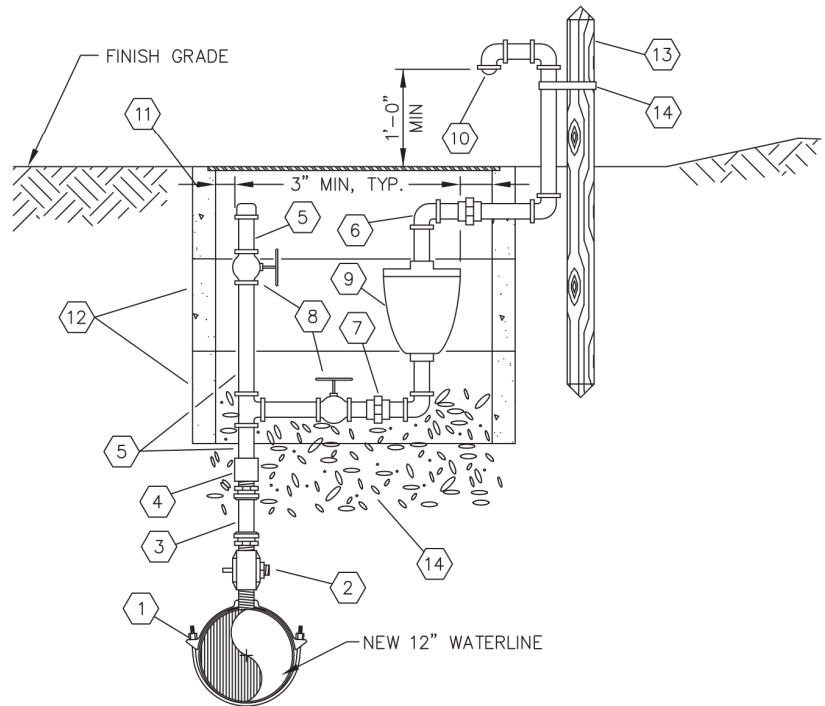


Figure 13-27. A section view detailing a 2" blow-off assembly for a 6" water main line.
(Courtesy of PACE Engineers, Inc.)



- | | | | |
|---|---|----|---|
| 1 | 2" SERVICE SADDLE | 9 | VAL MATIC COMBINATION AIR VACUUM RELEASE VALVE |
| 2 | 2" FORD AWWA/CC TAPER TO PVC CORPORATION STOP | 10 | BRASS INSECT SCREEN OVER END |
| 3 | 2" SCH. 80 PVC PIPE | 11 | PIPE INC. J20C-H VAULT |
| 4 | 2" FORD PVC TO FEM. I.P. COUPLER | 12 | (2) PIPE INC. J20C-H RISERS |
| 5 | 2" G.I. PIPE, TYP. | 13 | 4"x4"x6' CEDAR POST W/ 1ST QUALITY WATER BLUE ENAMEL |
| 6 | 2" G.I. PIPE FITTINGS, TYP. | 14 | METAL STRAP (PAINTED) |
| 7 | 2" G.I. UNION | 15 | GRAVEL BACKFILL UNDER VAULT FOR DRAINAGE. SHALL BE 1 1/2" MIN. CLEAN DRAIN ROCK. NO METAL PIPE SHALL CONTACT NATIVE SOIL. |
| 8 | 2" GLOBE VALVE | | |

STANDARD AIR RELEASE VALVE

N.T.S.

Figure 13-28. A section view of a water main line air release valve installation.

(Courtesy of PACE Engineers, Inc.)

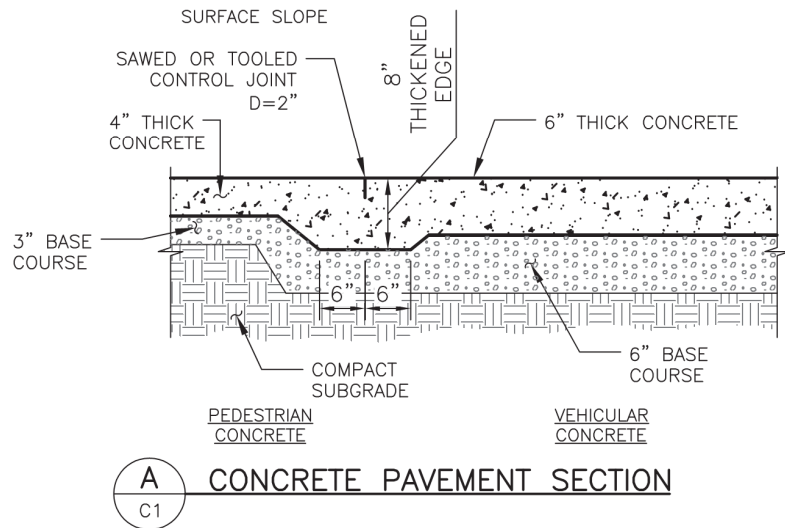


Figure 13-29. A section view showing poured-in-place concrete pavement construction.
(Courtesy of KPFF Consulting Engineers)

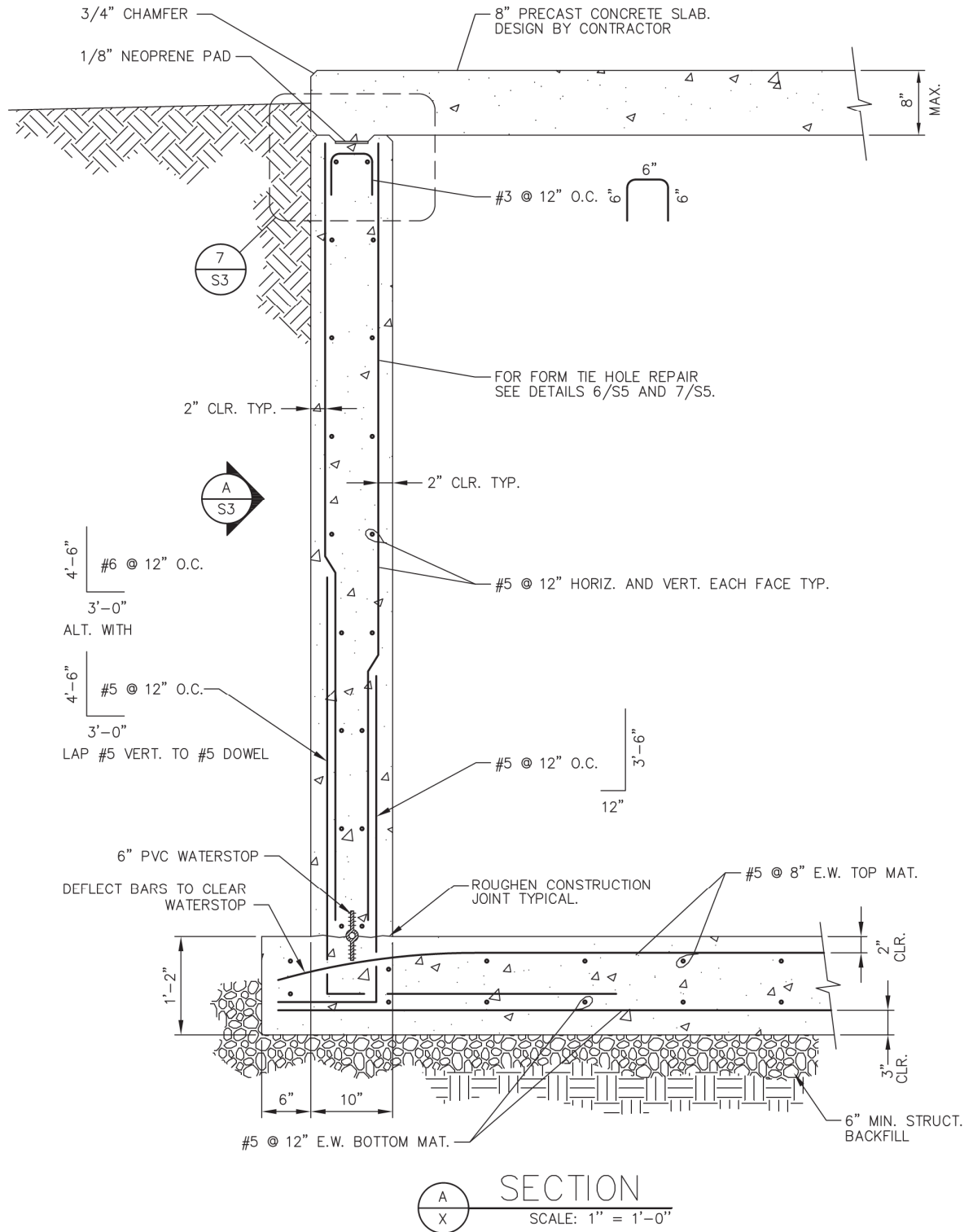
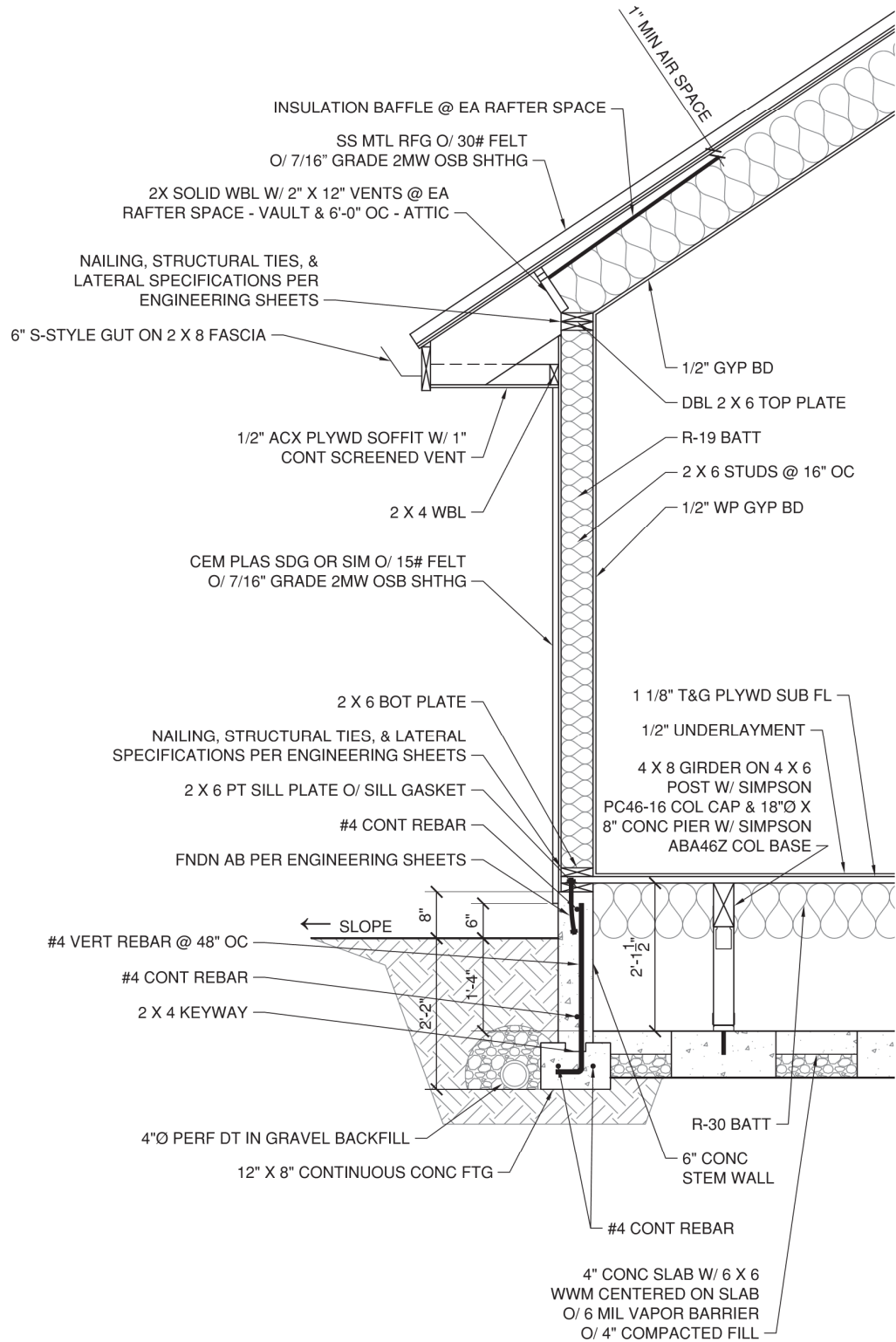


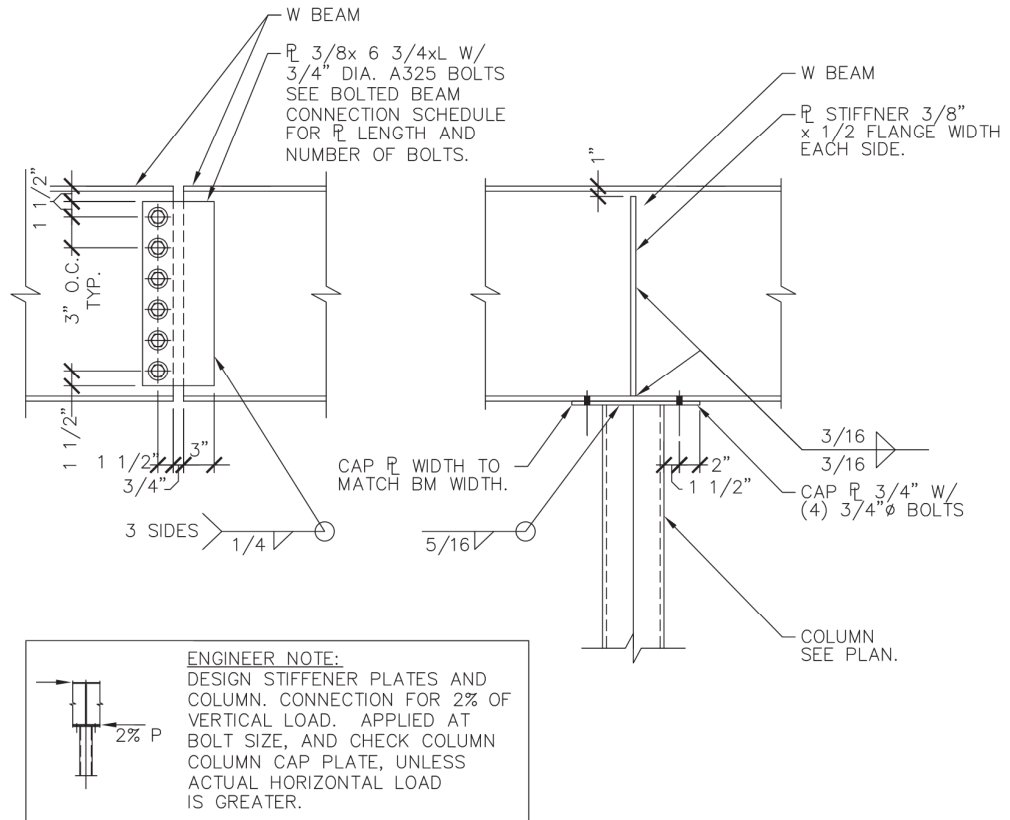
Figure 13-30. A section view showing steel reinforcing bar at a wall-to-floor slab connection.
(Courtesy of PACE Engineers, Inc.)



TYPICAL WALL SECTION

SCALE: 3/4" = 1'-0"

Figure 13-32. A typical section through the exterior wall of a wood-frame building.



STEEL BEAM TO COLUMN

N.T.S.

Figure 13-33. A detail showing how a structural steel beam is bolted and welded to form a connection to a column.

(Courtesy of PACE Engineers, Inc.)

Figure 13-34. A section view depicting the construction of a rock retaining wall.
(Courtesy of Chief Architect Software)

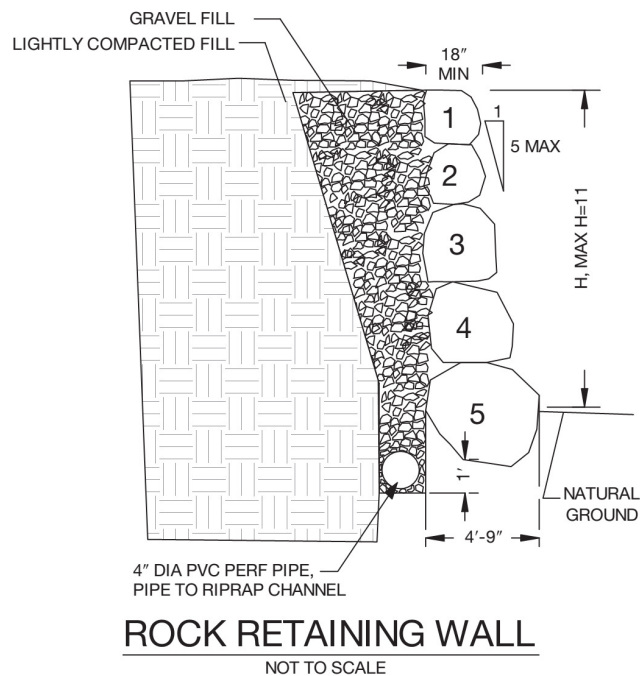
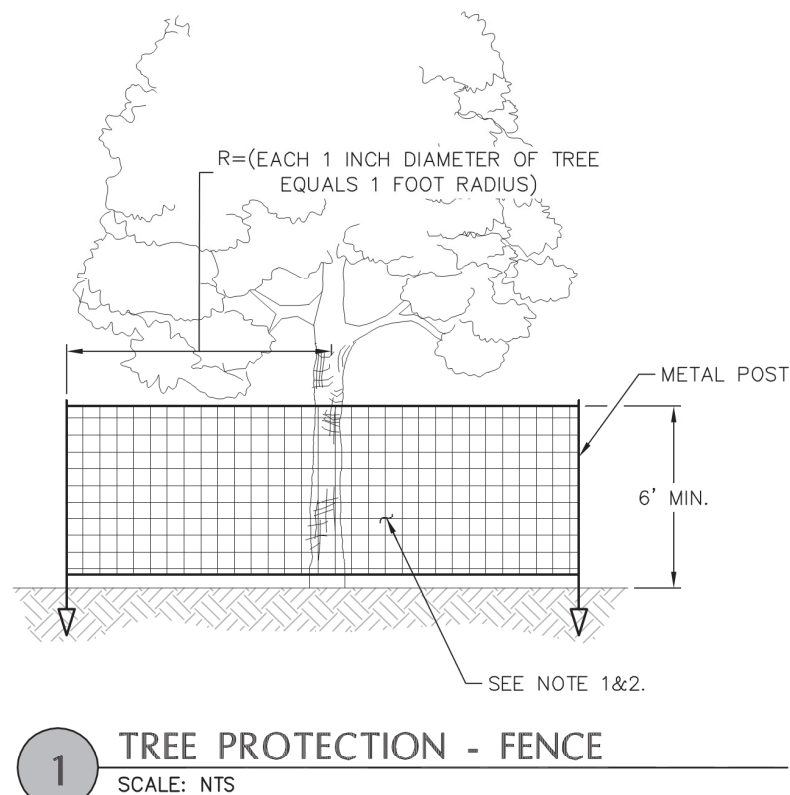
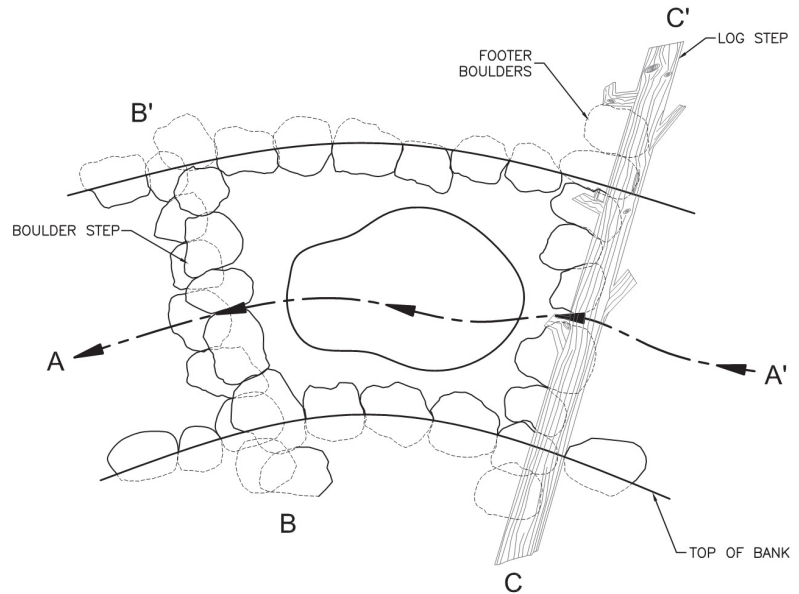


Figure 13-35. A section view describing the installation of a fence used to protect trees from damage during a construction project.
(Courtesy of KPFF Consulting Engineers)

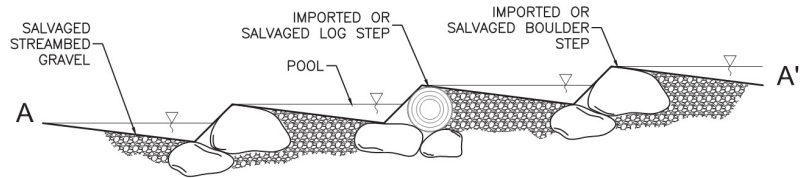




TYPICAL STEP-POOL PLAN

NOT TO SCALE

1
C05



TYPICAL STEP-POOL PROFILE

NOT TO SCALE

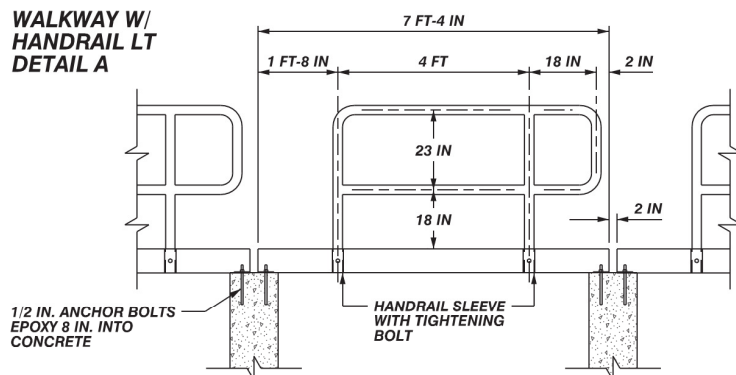
2
C05

Figure 13-36. Plan and profile views of a standard step pool design for a stream restoration project.

(© City of Portland, courtesy Bureau of Environmental Services)

Figure 13-37. A section view of a specific portion of hand-rail associated with a concrete irrigation structure removal project.

(Courtesy of Sage Civil Engineering)



CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

Part 1

Answer the following questions.

- 13-1** What is a detail view?
- 13-2** Explain how cross-referencing is used to organize and locate views in a set of drawings.
- 13-3** If a detail drawing is not a typical construction standard, where is it normally shown?
- 13-4** Name four different disciplines that require detail drawings.
- 13-5** List five road design features shown by detail drawings.
- 13-6** What is the difference between storm sewage and domestic sewage?
- 13-7** List three piping design features shown by detail drawings.
- 13-8** What are the three primary methods of concrete construction?

Part 2

Define the following terms.

- 13-9** Speed hump
- 13-10** Pictorial view
- 13-11** Catch basin

13-12 Erosion control

13-13 Potable water

13-14 Thrust block

13-15 Footing

Part 3

Study the portion of the standard sidewalk ramps with planter strip detail shown in Figure R13-1 to answer the following questions. The drawing is also available for download and viewing. Go to www.pearsonhighered.com/careersresources/, navigate to this textbook and chapter, and download the Chapter 13 Standard Sidewalk Ramps.pdf.

13-16 What type of drawing is shown at the top?

13-17 How many sections are cut on this drawing?

13-18 What section shows the minimum ramp width?

13-19 What is the minimum ramp width?

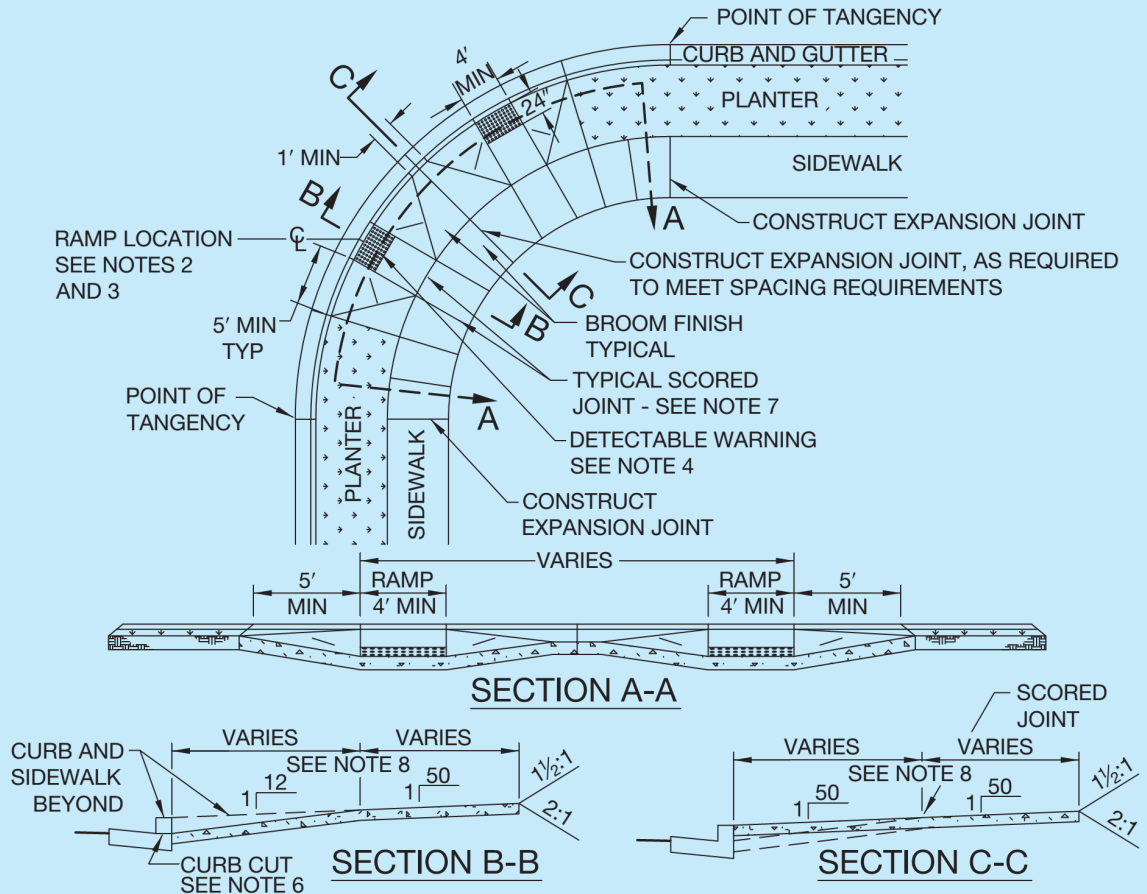
13-20 What features are located between the road and the planter strip?

13-21 What shapes are aligned on a square grid in the detectable warning area of the ramp?

13-22 What are the two grade slopes used on the ramp?

13-23 What standards must the sidewalk ramp meet?

- 13-24** What are the slopes for cut and fill at the inside of the curve on the ramps?
- 13-25** What drawing is to be referred to for sidewalk widths, planter strip widths, and sidewalk panel dimensions?
- 13-26** What compressive strength should the concrete have?
- 13-27** What note should be referred to for details on a typical scored joint?



NOTES:

1. Sidewalk ramp shall meet *ADA Standards*.
2. Engineer shall prepare a site-specific drawing for each ramp, accepting full responsibility for correcting all unacceptable ramp construction resulting from applying this drawing "as is".
3. Each ramp shall be located relative to crosswalk or stop line.
4. Detectable warning shall be 24 inches long in the direction of travel and full width of the ramp, made of concrete imbedded yellow tiles, that have truncated domes aligned on a square grid with its gridlines parallel and perpendicular to the centerline of the ramp, from the approved list in the *Engineering Design Manual, Sec 210.10*.
5. Concrete shall have a compressive strength of 4,000 psi at 28 days.
6. Bevel the curb cut from gutter to back of curb at 8.33% (1:12).
7. Score at grade changes, surface texture changes and at other points shown. Edges shall be shined.
8. For sidewalk and planter strip widths and sidewalk panel dimensions, see *Beaverton Standard Dwg 215*.
9. Curb inlet or catch basin shall not be allowed in front of sidewalk ramp.
10. A single ramp may be used at 'T' intersections at the locations shown in the diagram in the *Engineering Design Manual, Sec 210.10*.

STANDARD SIDEWALK RAMPS WITH PLANTER STRIP

Figure R13-1

Courtesy of PACE Engineers, Inc.

PROBLEMS

Follow the specific instructions to complete each problem.

Part 1

Draw the specified details using an ANSI A or ANSI B size sheet when possible. Determine the appropriate scale for plotting purposes and for text height. Construct the drawings using accurate dimensions. Use values for unspecified dimensions based on your experience, research, and measurements. Use appropriate graphic patterns when necessary. Include all notes and details. Use a basic border and title block, and complete all necessary title block fields.

P13-1 See Figure P13-1.

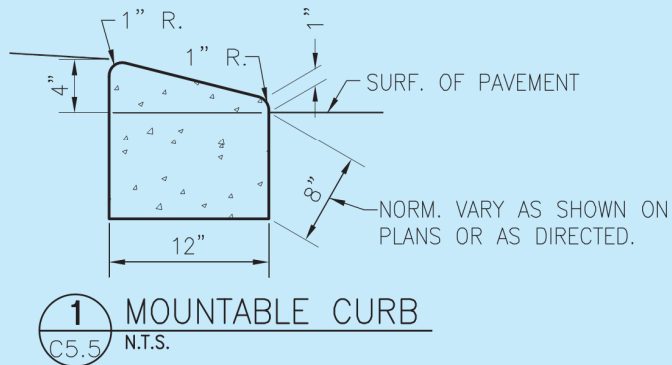


Figure P13-1
Courtesy of Otak, Inc.

P13-2 See Figure P13-2.

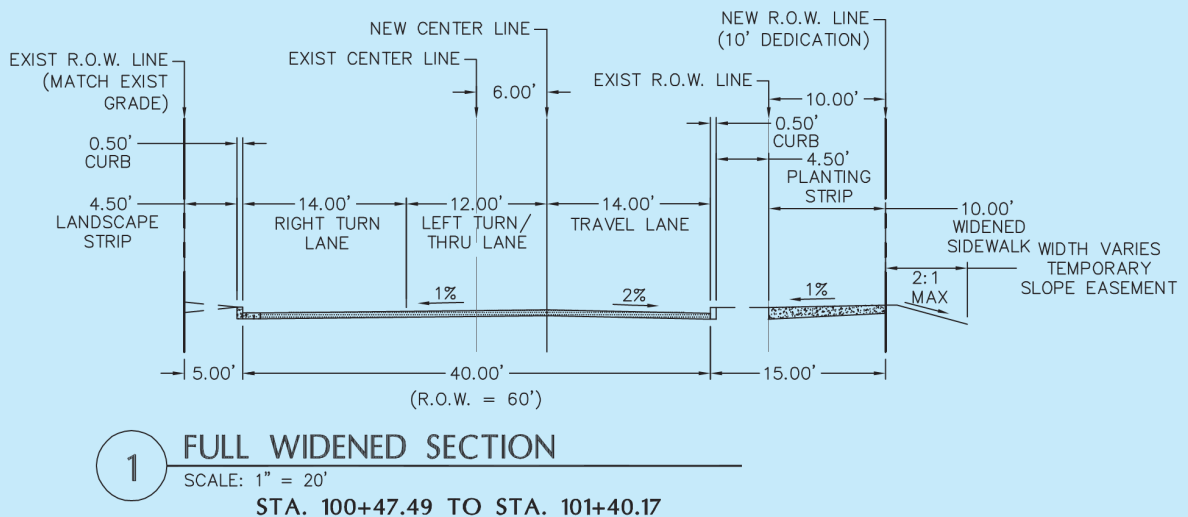
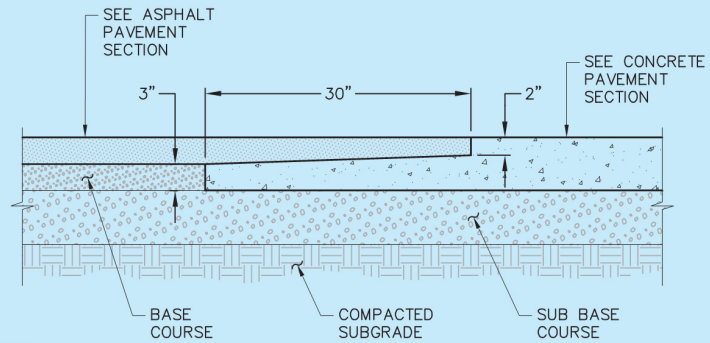


Figure P13-2
Courtesy of KPFF Consulting Engineers

P13-3 See Figure P13-3.



NOTES:

1. CONSTRUCT CONTRACTION JOINTS AT 15' MAX. SPACING AND AT RAMPS. CONSTRUCT EXPANSION JOINTS AT 200' MAX SPACING AT POINTS OF TANGENCY AND AT ENDS OF EACH DRIVEWAY.
2. PROVIDE MEDIUM TO COARSE BROOM FINISH.

2B

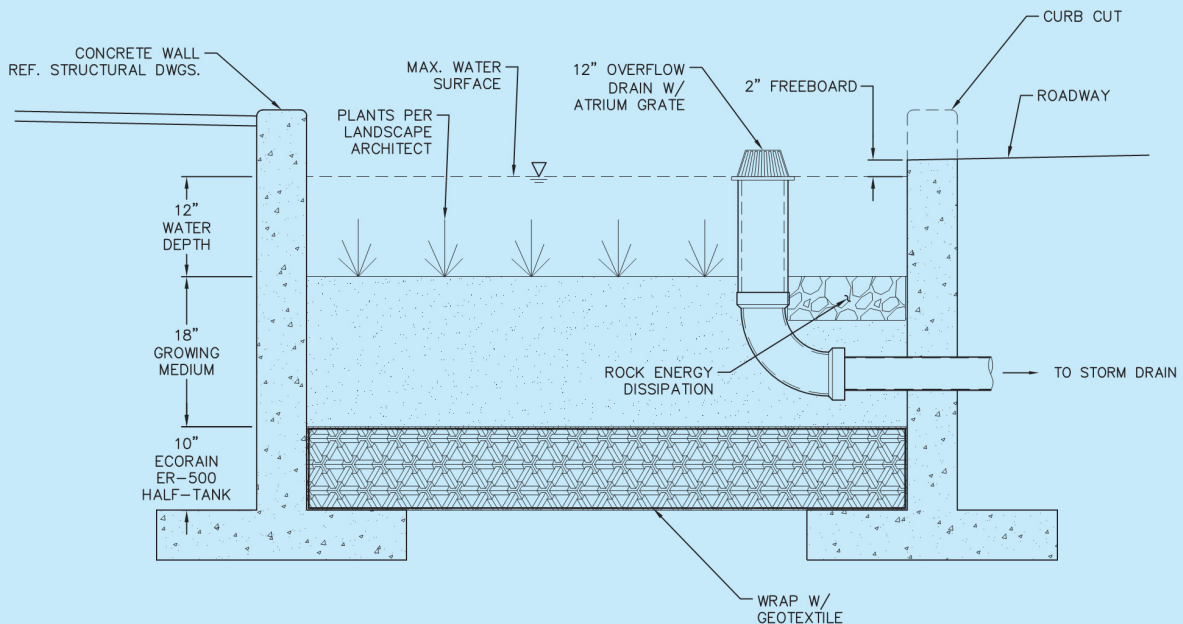
TRANSITION ASPHALT TO CONCRETE

SCALE: NTS

Figure P13-3

Courtesy of KPFF Consulting Engineers

P13-4 See Figure P13-4.



C

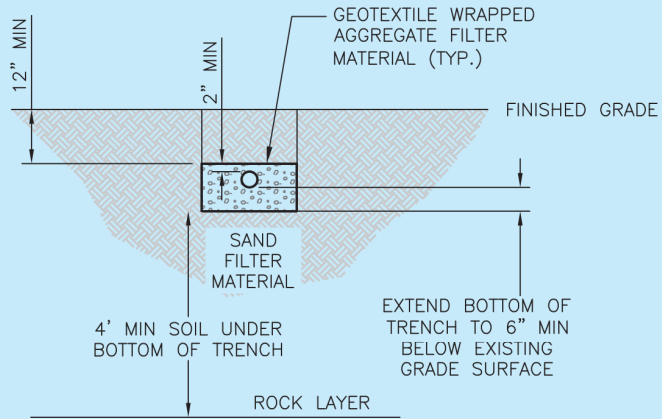
**CATEGORY 4
FLOW-THROUGH PLANTER - UNLINED**

SCALE: NTS

Figure P13-4

Courtesy of KPFF Consulting Engineers

P13-5 See Figure P13-5.



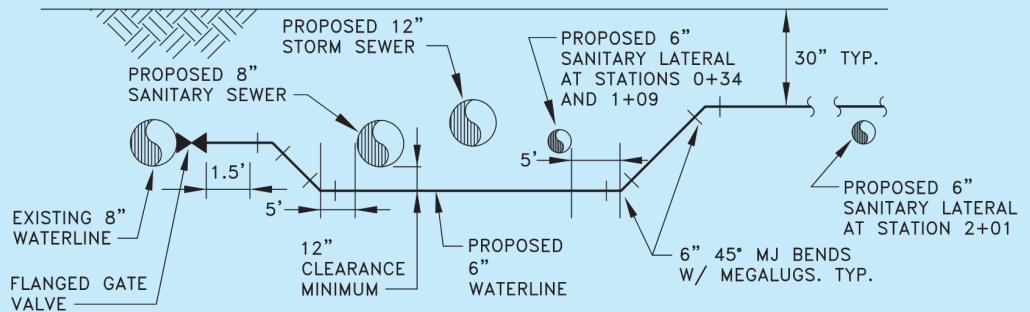
NOTE:
NOTIFY ENGINEER IF CODE MINIMUM DIMENSIONS
CAN NOT BE MET.



Figure P13-5

Courtesy of KPFF Consulting Engineers

P13-6 See Figure P13-6.



NOTE:

- (1) CONTRACTOR TO CONSTRUCT PROPOSED WATERLINE AND SANITARY SEWER SO THAT NO PIPE JOINTS ARE PRESENT WITHIN 5 FEET OF WATERLINE/SANITARY SEWER CROSSING.
- (2) CONTRACTOR TO CONSTRUCT PROPOSED WATERLINE AND SANITARY SEWER SO THAT A MINIMUM SEPARATION OF 6 INCH IS OBTAINED AT ALL CROSSINGS.
- (3) CONTRACTOR TO CONSTRUCT PROPOSED WATERLINE WITH CDF BACKFILL IF MINIMUM SEPARATION IN NOTES 1 AND 2 CANNOT BE SATISFIED.
- (4) PRIOR TO CONSTRUCTION CONTRACTOR TO STAKE WATERLINE WITH GRADES TO ENSURE THAT LINE MEETS DESIGN REQUIREMENTS.



Figure P13-6

Courtesy of PACE Engineers, Inc.

P13-7 See Figure P13-7.

Figure P13-7

Courtesy of PACE Engineers, Inc.

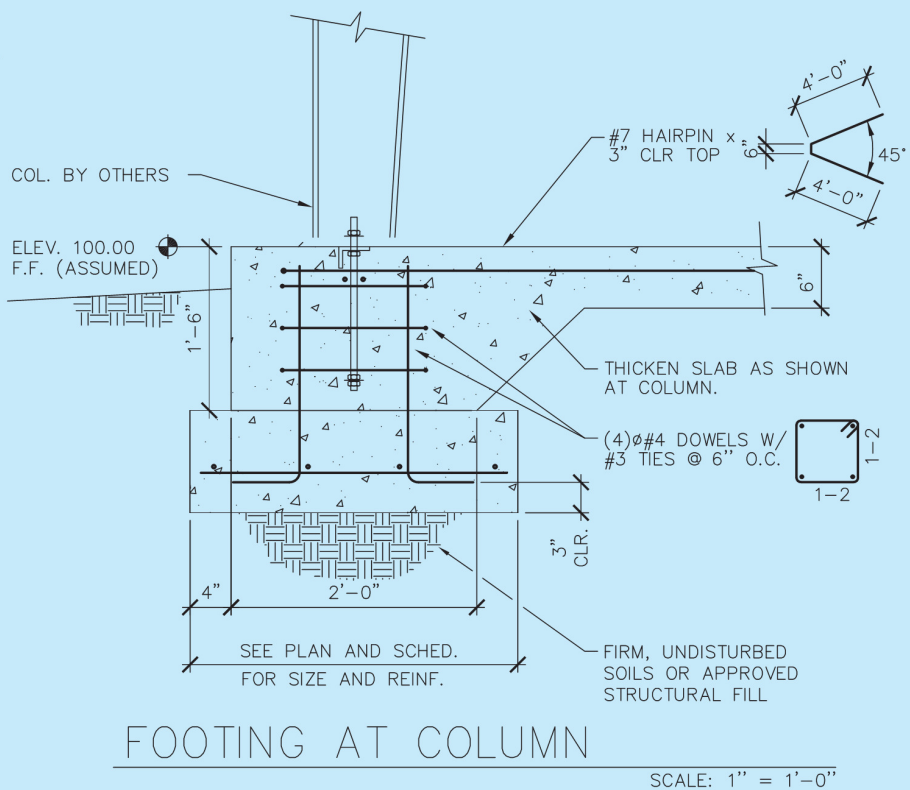
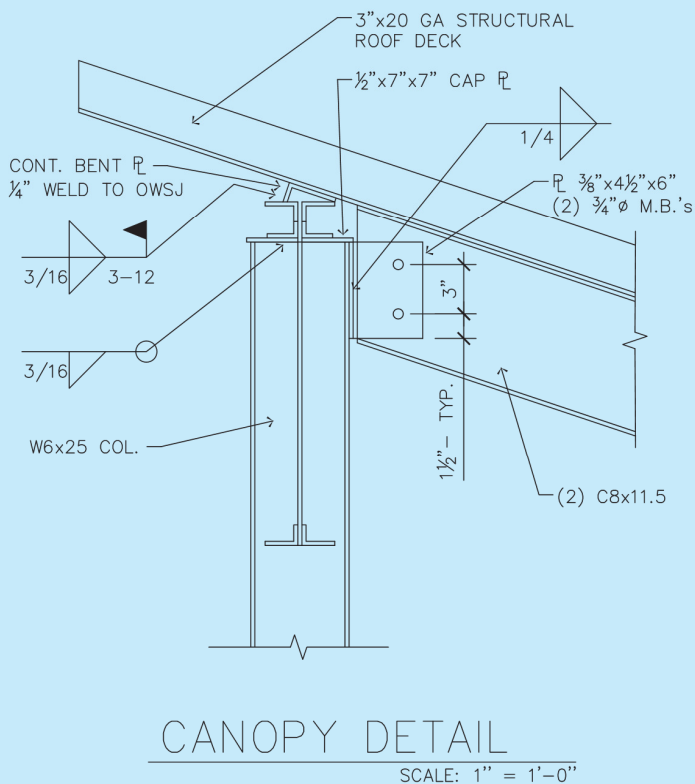


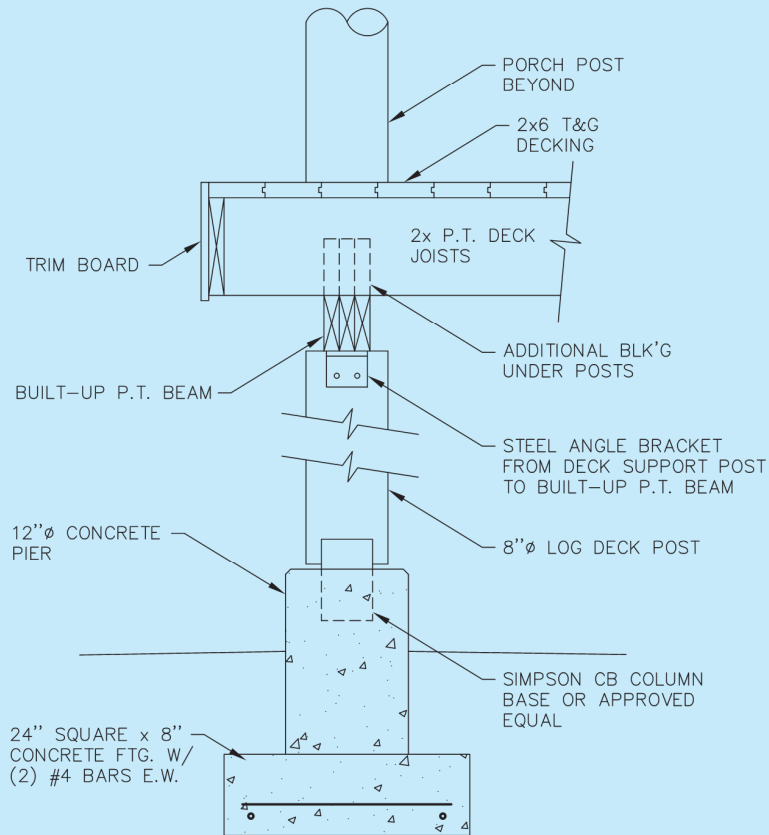
Figure P13-8

Courtesy of PACE Engineers, Inc.

P13-8 See Figure P13-8.



P13-9 See Figure P13-9.



PORCH PIER CONNECTION

SCALE: 1" = 1'-0"

Figure P13-9

Courtesy of PACE Engineers, Inc.

Part 2

Complete the following assignment and presentation.

P13-10. Contact local civil engineering firms in order to complete this problem. Assemble a collection of detail drawings for a variety of disciplines. Create a storage and retrieval system that allows all students or employees to access the files. Print a document that contains a list of all details, arranged by discipline. Include the file name and path, plotting scale, file size, and any other information deemed appropriate. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.

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CHAPTER

14

Introduction to Geographic Information System (GIS)

Learning Objectives

After completing this chapter, you will be able to:

- Answer questions related to GIS technology.
- Describe topology.
- Identify various GIS applications.
- Compare and contrast GIS and CADD.
- Show a soil map in raster GIS format.

Key Terms

Geographic information system (GIS)
Spatial
Open source application
Desktop GIS
Mobile GIS
Server GIS
Web GIS
Georelational data model
Layer
Point feature
Line feature
Route feature
Polygon feature
Area feature
Region feature
Voxel feature
Database management system (DBMS)
Database (DB)
Query
Hypermedia
Rasterization
Vectorization
Topology
Point-in-polygon
Polygon overlay
Buffering
Nearest-neighbor
Network analysis
Extracting
Generalizing
Land use planning
Natural resources management
Geocoding
viewshed determination

A **geographic information system (GIS)** is an electronic system used to collect, manage, analyze, and present spatial and attribute data. **Spatial** refers to the location of a feature. Attribute data describes characteristics of a feature. GIS provides a set of tools for solving spatial problems by working with spatial and attribute data. Graphics such as maps, tables, and charts are used to visualize the processed information. GIS technology is used for countless different applications from land use planning and facilities management to scientific investigations and market analysis. This chapter is an introduction to GIS, and explains a variety of basic GIS concepts and applications.

GIS Software Products

GIS software is generally used to view, create, edit, manage, and analyze a collection of data, known as a data set. GIS software can then be used to generate maps to communicate the location and description of objects from different data sets. Many GIS software manufacturers exist, and numerous products are available to meet industry needs. GIS software is available in propriety commercial and open source desktop, mobile app, server, and web formats. An **open source application** is a program that you can use and modify for free. **Desktop GIS** uses software loaded on your desktop computer to process GIS. A **mobile GIS** app allows you to access GIS data and functionality on your mobile device, and is often used to collect and analyze data in the field. **Server GIS** is an evolution of desktop GIS that allows you to access GIS data and functionality through networks, known as geoprocessing. **Web GIS** uses web technologies to communicate between a GIS server and a client web browser, desktop application, or mobile application.

The design of a GIS software interface lends itself to specialized third-party applications. The number and diversity of these applications increase as different businesses adopt GIS technology. Third-party applications include those for exploring natural resources, dispatching emergency services, and evaluating the impact of global warming. GIS may either provide the input data or serve as the user-friendly front end for these applications.

Note: The following is an alphabetical introduction to common commercial GIS software products at the time this textbook was published. There are many other GIS software manufacturers and numerous other GIS software products. The following material and software content throughout this textbook are not intended to promote or endorse any software manufacturer or product.

Autodesk, Inc.

Autodesk offers a wide variety of software. AutoCAD is a general-purpose two-dimensional (2-D) and three-dimensional (3-D) CADD software, and is the core Autodesk product. Autodesk provides variations of AutoCAD for unique markets such as AutoCAD Map 3D for GIS and mapping. For more information about Autodesk, go to www.autodesk.com.

Bentley Systems, Inc.

Bentley Systems focuses on software for engineering and construction infrastructure design, documentation, and operation. MicroStation is a general-purpose 2-D and 3-D CADD software, and is the primary Bentley Systems product. MicroStation also acts as a platform for other Bentley Systems software. Bentley Map and variations of Bentley Map provide tools for GIS and mapping. For more information about Bentley Systems, go to www.bentley.com.

Caliper Corporation

Caliper is a developer of mapping and transportation software products. Maptitude GIS is the Caliper software for GIS and mapping. For more information about Caliper, go to www.caliper.com.

Esri, Inc.

Environmental Systems Research Institute, Inc., commonly known as Esri, produces complete GIS solutions for desktop, mobile, server, and Internet platforms. ArcGIS is an integrated family of GIS software products for building a complete GIS. The ArcGIS framework allows you to use GIS wherever it is needed. Products include ArcGIS for Desktop, ArcGIS Pro, and ArcGIS Online. ArcGIS for AutoCAD is an AutoCAD plug-in that allows you to use ArcGIS data inside of AutoCAD. For more information about Esri, go to www.esri.com.

Intergraph Corporation

Intergraph offers several software products for specific industries and projects, including the design, construction, and operation of plants, ships, offshore facilities, and transportation and utility systems. Intergraph GIS software includes GeoMedia, which is associated with the Hexagon Geospatial brand. For more information about Intergraph, go to www.intergraph.com.

Manifold Software Limited

Manifold Software provides the Manifold System GIS product available in a variety of versions including Personal, Professional, Enterprise, and Database Administrator editions. Manifold System provides integration of raster images, vector drawings, terrain surfaces, terrain visualization, full programming capability, and a web server. For more information about Manifold Systems, go to www.manifold.net.

Pitney Bowes, Inc.

Pitney Bowes offers a wide selection of products. MapInfo Professional and MapInfo Discover are the Pitney Bowes applications for GIS and mapping and are available in different versions. For more information about Pitney Bowes, go to www.pitneybowes.com.

GIS is a tool for recording and tracking data, similar to a spreadsheet, or even a hard copy filing system. A spreadsheet is used for number-related information processing that is displayed in table format. GIS is the geographical equivalent of a spreadsheet that can provide answers to questions that have spatial dimensions. Unlike other data systems, such as spreadsheets and computer programs that use spatial data, GIS tracks information that is relevant to a specific location in space and is capable of powerful statistical and spatial operations. Figure 14–1 shows how GIS integrates geographic coordinates and statistical data in a system used to capture, input, manipulate, query, analyze, and output information.

The two related parts of geographical information are spatial and attribute data. Spatial and attribute data are related by a common item that has a unique value. This relationship is called the **georelational data model**. The georelational data model offers a consistent framework for analyzing spatial data. Figure 14–2 shows a GIS application used in the forestry industry to document and manage stands of timber located in a specific area. This example contains graphic data and a map, as well as tabular data. The map provides the spatial data, which in this example is the location of all forest stands in the Appomattox-Buckingham State Forest of Virginia. The table lists the attribute data, which in this figure includes a variety of information such as the identification, type, age, and size of each forest area. Notice how the spatial data and attribute data can be correlated to effectively understand the characteristics of each stand of timber. Study the portions of the map and table to further understand the GIS shown in Figure 14–2. You will learn more about spatial data and attribute data, and explore other GIS applications later in this chapter.

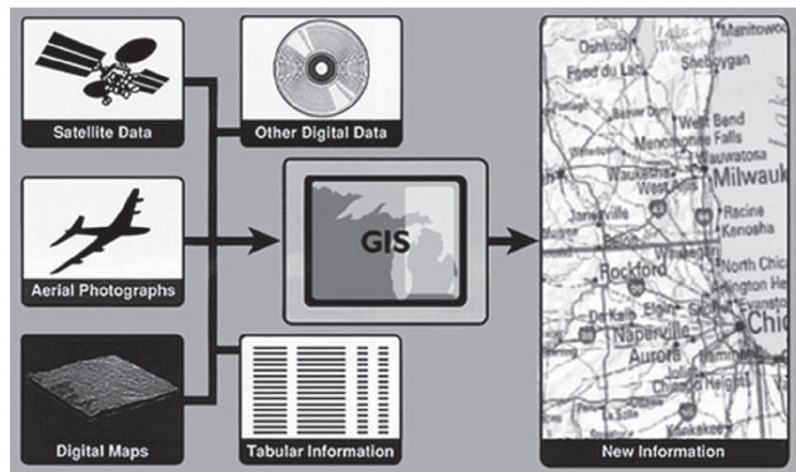


Figure 14–1 The concept of how GIS integrates information in different forms to output new data.

(Courtesy of the U.S. Geological Survey)

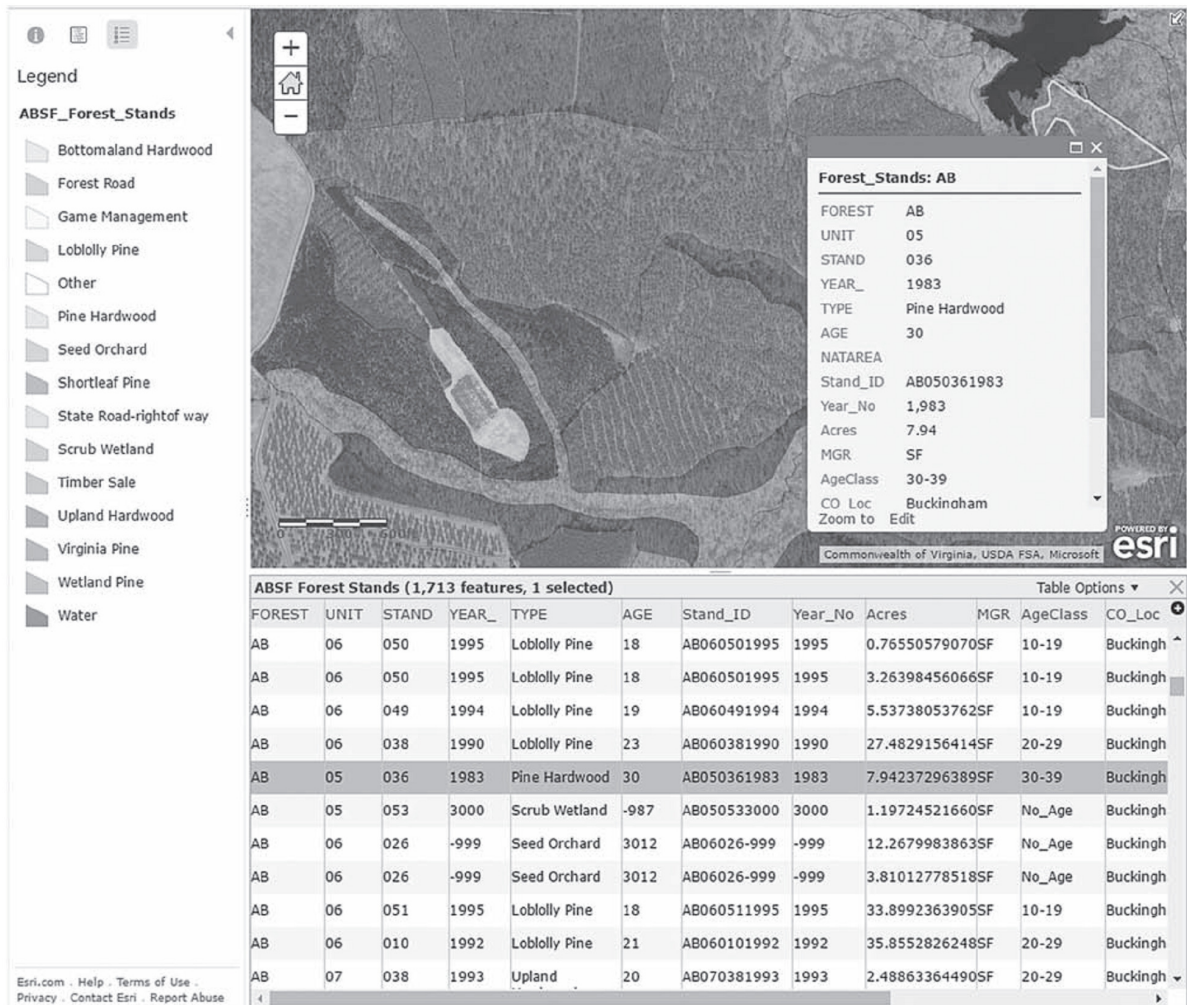


Figure 14–2 A GIS application used in the forestry industry to document and manage stands of timber located in the Appomattox-Buckingham State Forest of Virginia. The map provides the spatial data and the table provides the attribute data.

(Courtesy of Esri and the Virginia Department of Forestry, State Forest)

Layers

A GIS stores multiple layers of reality. A **layer** is a logical grouping of data. A GIS map uses layers to organize real-world information. You can consider layers to be a series of map overlays. A GIS map includes as many layers as necessary to present the desired data. Figure 14–3 displays layers applied to a **US Topo** quadrangle map created by the U.S. Geological Survey (USGS). This example shows how a unique symbol defines each different group of geographic objects. The orthoimage, shaded relief, contour line, hydrography, transportation, woodland area, geographic name, and UTM grid line object groups are layered on each other to create the complete map. In Figure 14–2, layers are used to organize the different forest stands, forest roads, wildlife game management areas, timber sale areas, and surface water. In this example, the layers are organized to display a

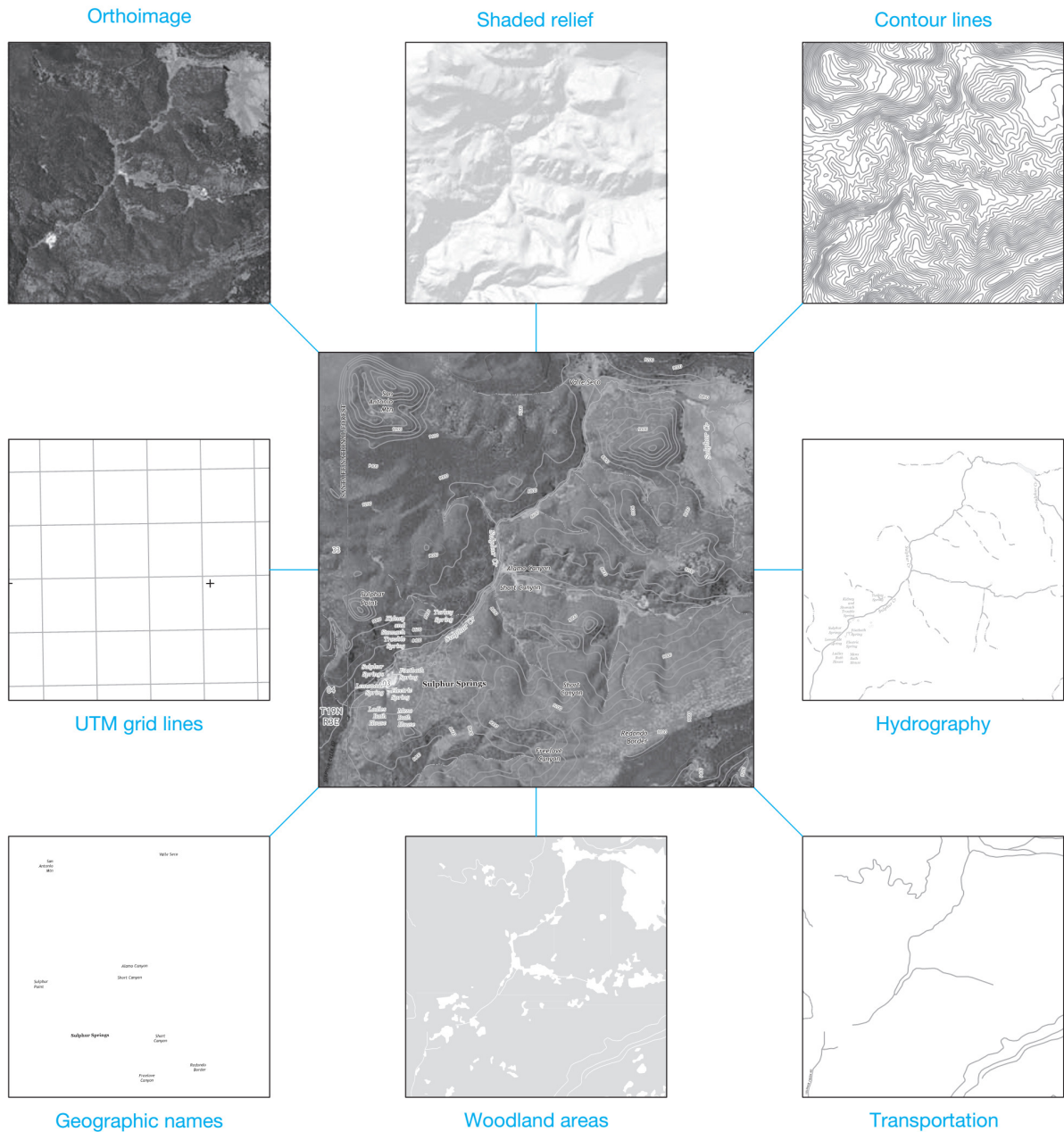


Figure 14-3 The concept of layers applied to a portion of the Valle San Antonio, New Mexico quadrangle map.
(Map courtesy of the U.S. Geological Survey)

specific hierarchy of information on the map. Notice how the map legend in Figure 14-2 identifies the layers.

Spatial Data

Much of the information that utilities, planners, engineers, and governments use relates to locations on the Earth. The three primary feature types that GIS programs store as spatial data are point, line, and

polygon features. A **point feature** is an item at a single geographic coordinate point such as a tree, survey marker, power pole, manhole, well, or destination. A point feature has a single latitude and longitude, and/or other coordinate, address that defines its location. A **line feature** is a series of geographic coordinate points joined together to form a curve, such as a stream, road or railway centerline, power line, sewer line, or contour line. A line feature has two or more latitude and longitude coordinates connected together to define a consecutive series of locations. A **route feature** is a linear feature used by the transportation industry.

A **polygon feature**, also known as an **area feature**, is a series of geographic coordinate points joined together to form a boundary such as a specific type of soil or forest, a parcel of land, urban area, or census tract. A **region feature** is a set of overlapping or separate polygons. An example of a region with nonoverlapping polygons is the United States displayed on a map of the Earth with all the countries shown. The U.S. appears as separate polygons because the contiguous U.S. is separated from Alaska and Hawaii. An example of a region with overlapping polygons is seen in the mineral extraction industry, where different types of minerals may be in regions that are connected or overlapping. A **voxel feature** is a 3-D polygon used to model flow of air and water.

Figure 14–4 shows a GIS application used by a civil engineering infrastructure department to document and manage a sewer system. Point features in this example are sanitary sewer facilities, manholes, and pumps; and storm sewer facilities, inlets, manholes, outlets, and pumps. In Figure 14–4, a sanitary sewer manhole is selected and the attributes of the manhole are listed in the table below the map. Line features in this example are sanitary sewer lateral and main lines; and storm sewer channels, culverts, and pipes. Polygon features in this example are parcels of land, storm sewer drainage basins, parks, and greenways.

Note: Spatial data can be represented differently depending on map scale. For example, on a small-scale map of the United States, cities may be shown as point features. On a larger-scale map of a state or county, it is possible to show the boundaries of cities, and therefore, cities may appear as polygon features.

Attribute Data

The term attribute can have a variety of related definitions. In CADD, for example, an attribute typically refers to text-based data assigned to a specific object. An attribute is also a characteristic or property of an object, such as weight, size, or color. In GIS applications, attribute data is linked in the GIS to spatial data that defines the location. A GIS might be described by characters, images, numbers, values, and CADD drawings. Attributes are commonly stored in tabular format and linked to a feature. For example, the attributes of a sanitary sewer manhole, such as the manhole selected in Figure 14–4, can include a unique identifier, diameter, material, invert in and out elevations,

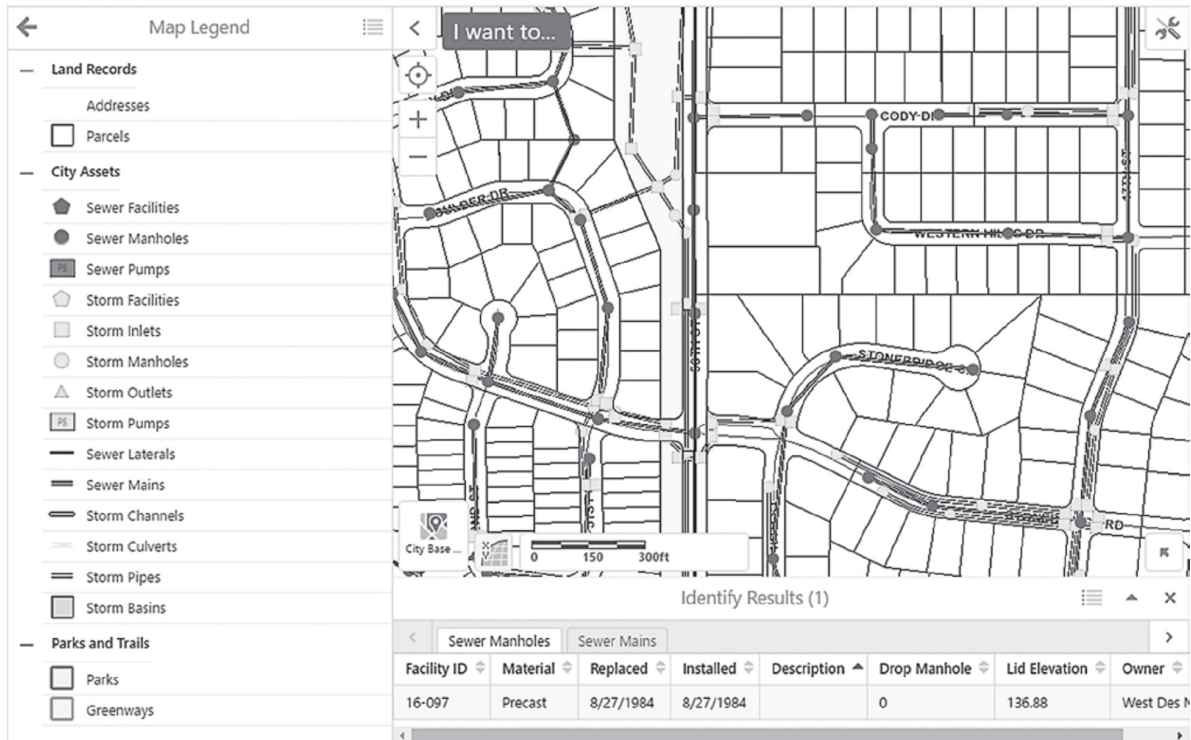


Figure 14–4 A GIS used by the City of West Des Moines, Iowa to document and manage the city sewer system. The map includes spatial data as point, line, and polygon features.
(Courtesy of Esri and the City of West Des Moines, Iowa)

rim elevation, condition, and date of installation. The unique identifier attribute is especially important, and provides a link by which the features can be related to other features and other data tables.

GIS programs use relational database management systems (RDBMSs) to relate information from different files. Each related file contains one data item that is the same. RDBMS software programs store data in a manner that allows tables to be joined together by linking a common item of data, known as a key. In general, a **database management system (DBMS)** is a collection of programs that let you store, modify, and extract information from a database. A **database (DB)** is an electronic filing system that provides a collection of information organized for a computer program to rapidly select desired pieces of data. Requests for information from a DB are made in the form of a query. A **query** is a question that allows you to find the desired information in the database. An example of a query in the forestry database example associated with Figure 14–2 is Select All Species Where = “Loblolly Pine” and Age <30. This query requests all records of forest stands with loblolly pine trees younger than 30 years of age. Most DBMSs allow you to output information in a report with graphs and charts or graphically by quickly changing symbols on a map.

Data tables can be related, or joined, to features in a feature group, usually by a unique identifier, to provide additional information about the feature. For example, paths to photos of a manhole taken over several years to represent the condition of the manhole

can be stored as attributes of the manhole point feature. This technique may require an additional attribute for each photo up to the maximum number of photos typically stored. This would make the attribute table for the manhole feature group cumbersome. Using data tables, a separate table can be created with an attribute entry for the unique identifier associated with the subject of the photo; in this case the manhole. The other attributes in the photo table describe the photo, including the location of the photo. The photos table is related to the feature class by the unique identifier. When the manhole is selected on the map, the list of photos of the manhole appear.

Note: Hypermedia is a system for referencing and retrieving different forms of digital data. Hypermedia, such as satellite images, architectural and engineering drawings, survey information, aerial photography, video, and sound is becoming more integrated with GIS. Referencing digital data geographically allows the end user to access and analyze data in new ways. This analysis reveals new associations and existing relationships.

Data Formats

Spatial data can be stored as vector or raster formats (see Figure 14–5). Each format has advantages based on the application and environment. Vector format, shown in Figure 14–5a, is the most common format for storing spatial point, line, and polygon features. Vector formats work best with data that has well-defined boundaries such as parcels, street right-of-ways, political boundaries, and other human-made artificial boundaries. Vector format provides greater accuracy and resolution than raster format. Vector format can also store data in a minimum amount of disk space.

Raster format, shown in Figure 14–5b, consists of an array of cells, sometimes called grids or pixels (picture elements). Each cell references a row and column, and it contains a letter or number representing the type or value of the attribute being mapped. Scanned images and remote sensing data, including aerial and space

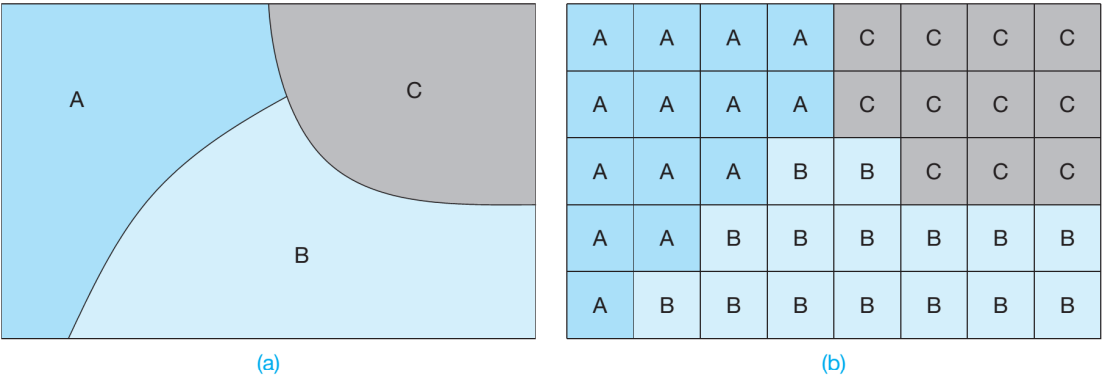


Figure 14–5 (a) The basic concept of spatial data in vector format. (b) The same spatial data shown in raster format.

photographs and satellite imagery, use the raster format. Electrostatic plotters produce maps in a raster format, at a resolution that makes the lines appear smooth.

Raster formats work best with features that are continuous and that change their characteristics gradually over distance such as soils, vegetation, and wildlife habitat. Spatial analysis is generally easier to perform with a raster format. Unlike the vector format, which calculates line intersections, the raster system evaluates the values contained within each overlying cell. Two principal disadvantages of raster formats are the large amounts of storage space required to hold the data and the lack of accuracy when using large-scale maps.

Data Format Conversions

Rasterization is the conversion of vector data to raster (see Figure 14–6). **Vectorization** is the conversion of raster data to vector. Vectorization computer software allows you to set the desired variables in the conversion process to suit the intended purpose. You can change the variables so that the vector outputs are designed specifically for the project. For example, a wolf biologist may want to set different parameters than a biologist studying mice when generating habitat polygons from a raster image. Detail and accuracy in the change of habitat from grassland to woodland may be more significant in the research of mice. As 3-D scanning and remote sensing become popular methods of building and updating GIS databases, GIS software packages have included the capability to convert between raster and vector formats.

Topology

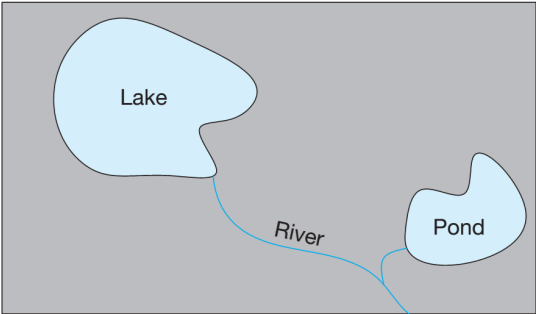
Topology is a branch of mathematics that deals with relationships among geometric objects. Topology defines and manages relationships such as connectivity, adjacency, and contiguity. These relationships are intuitively obvious to humans but difficult for a computer to determine. Topology explicitly defines boundaries for a computer. Furthermore, topology is used to identify editing errors, perform polygon overlays, and conduct network analysis.

If you build line topology on a street base, for example, all lines know where they connect and how they relate to each other. This allows you to find the best route from one point to another on your street base. Topology adds spatial intelligence to points, lines, and polygons. Each polygon knows the *XY* coordinates of the beginning and ending points of the lines defining the polygon. All connecting lines must have the same *XY* coordinates when building topology.

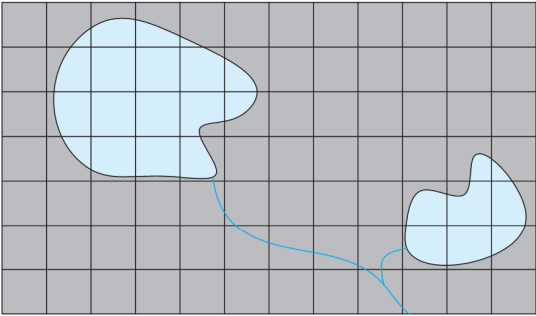
Data Analysis

A GIS consists of computers, software, data, and tools for analyzing features on the Earth as related to their geography. GIS allows you to make models and decisions based on spatial and attribute data. Data analysis generally requires information about the feature name, type, and attributes; attribute values; and geographical position. The feature

Figure 14-6 The concept of creating a raster GIS hydrography map from a vector GIS map.



Hydrography reality



Reality with grid overlay

0	1	1	1	1	0	0	0	0	0	0	0
0	1	1	1	1	1	0	0	0	0	0	0
0	1	1	1	1	1	0	0	0	0	0	0
0	1	1	1	1	0	0	0	0	0	1	1
0	0	0	0	2	2	0	0	0	1	1	1
0	0	0	0	0	2	2	2	2	1	1	1
0	0	0	0	0	0	0	0	2	2	0	0

ID	Feature
0	No water feature
1	Water body
2	River

Raster format

name is an identification or description of the object to analyze such as a tree, manhole, temperature, or restaurant. The feature type is a point, line, or polygon. Feature attributes represent the information that you want to know about the feature, and the attribute values are the responses that you provide for the feature attributes. The geographical position is the spatial address, often latitude and longitude, linked to the feature that locates the feature on the Earth.

Spatial analysis permits synthesis and data display in new and creative ways, using spatial and attribute queries. A GIS makes connections between activities based on location. A connection can

suggest new insights and explanations. For example, GIS can link toxic waste records with school locations through geographic proximity. Spatial queries act on points, lines, and polygons. The following are examples of spatial analysis:

- **Point-in-polygon**—Locates points that are within polygons (see Figure 14–7).
- **Polygon overlay**—Generates new polygons from two or more existing polygons.
- **Buffering**—Creates new polygons around a set of points, lines, or other polygons.
- **Nearest-neighbor**—Identifies features that are closest to another feature.
- **Network analysis**—Performs flow analysis, determines routing, or orders stops.

Attribute queries act on the features' attributes. Examples of this type of operation are extracting and generalizing. **Extracting** reselects a subset from existing features. **Generalizing** combines polygon features based on similar attributes.

Data Display

Graphics such as maps, tables, and charts are often the result of GIS data collection, management, and analysis. Maps communicate geographical information in a clearly understood and easily interpreted format. GIS maps allow relationships between different types of data

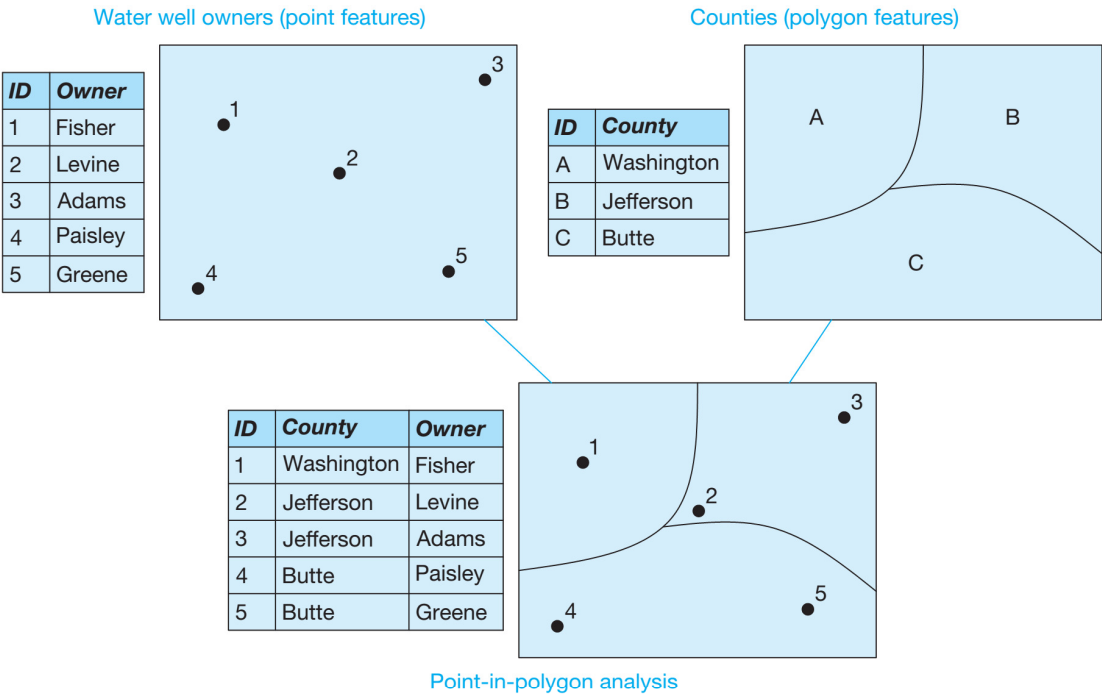


Figure 14–7 A basic example of a point-in-polygon spatial analysis used to map property owners with water wells in different counties.

to be clearly seen. GIS programs do not necessarily have cartographic intelligence that guides operators in the choice of map symbols and other graphic effects. The programs have tools to symbolize maps and draw lines, titles, legends, text, and scale bars. You will see additional examples of GIS in the following section of this chapter.

Note: Due to the dynamic nature of GIS, ongoing training and education are essential. While training on specific GIS software is invaluable, a good understanding of GIS concepts is equally important. Anyone interested in working with GIS should consider obtaining an understanding of database manipulation and management, and some computer programming.

GIS Applications

GIS technology is used for countless different applications. A GIS can allow emergency planners to calculate emergency response times in the event of a natural disaster. Farmers use GIS to evaluate the effects of soil, water, and fertilizers in improving yields. Wildlife biologists can study the effects of deer populations on sustainability of reintroducing wolves to a certain geographical habitat, or to find waterfowl nesting wetlands that need protection from pollution. Shipping companies use GIS in routing of local delivery services, and scheduling of long-distance freight hauling. GIS technology allows workers to function more efficiently and effectively, and make better decisions based on better information. The following information highlights some of the various GIS applications.

Land Use Planning

Land use planning is the organized evaluation of physical, social, and economic land issues in a way that supports land users in making decisions that increase their productivity and sustainability, and meet the needs of society. Land use planning is one of the most common GIS applications, and is useful for everything from analyzing the effects of adding a bike lane to a street to identifying a suitable location for a new park. Some other land use applications include processing building permits, assessing taxes, inventorying vacant land, and adjusting school enrollment.

Figure 14–8 shows a GIS zoning map of a portion of the City of Gresham, Oregon used to analyze suitable areas for mixed-use development projects. In this example, according to the selected and highlighted area on the map, and the corresponding highlighted entry in the table below the map, it should take 10 to 15 minutes to walk to a light rail stop within the specified area. Figure 14–9 shows a GIS tax assessment map of a portion of the Town of Dedham, Massachusetts used to provide parcel information. In this example, a parcel is selected and highlighted in the map, and the parcel details are shown in a pop-up to the right of the cursor.

Natural Resource Management

Natural resources management describes the sustainable use of natural resources, such as land, air, water, minerals, plants, and animals. Some of the first GIS applications were in forestry. Private timber companies use GIS programs to assist with planning and managing timber ownership, plan harvest rotations, inventory timber and soil types, evaluate the potential board feet and value of a future stand of timber, and analyze the possible effects of disease from pests. Figure 14–2 shows a GIS application used in the forestry industry to document and manage stands of timber located in the Appomattox-Buckingham State Forest of Virginia.

The oil and gas industries use GIS extensively to identify and develop new prospects for exploration. They also use GIS to manage their current lease holdings and pipeline and production facilities. Figure 14–10 displays a GIS map of a portion of the State of Utah used to identify the location and details of oil and gas well surface points. In this example, a gas well surface point is selected and highlighted in the map. The attributes of the well are shown next to the point in the map and in the table below the map. Other natural resource management GIS applications include identifying wildlife habitats, analyzing environmental impacts, estimating earthquake impacts, and monitoring surface water pollution.

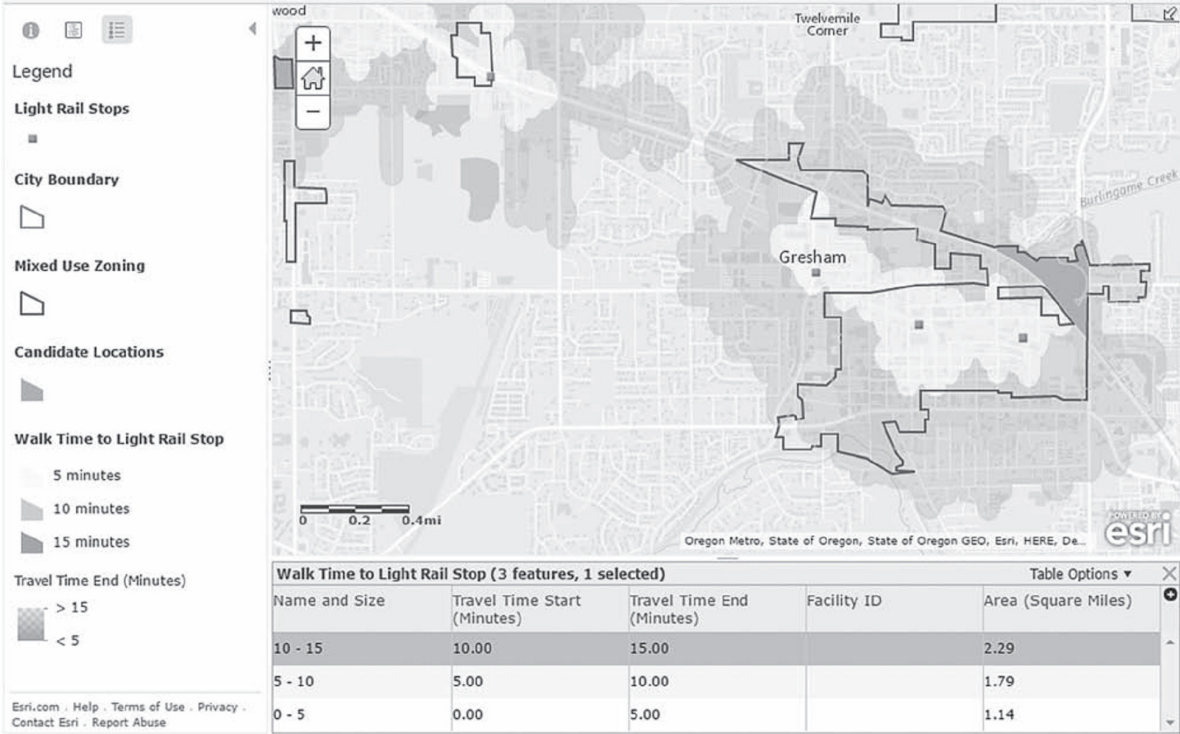


Figure 14–8 A GIS application used in land use planning to document and manage suitable areas of mixed-use development projects in the City of Gresham, Oregon. (Courtesy of Esri and Oregon Metro, State of Oregon)

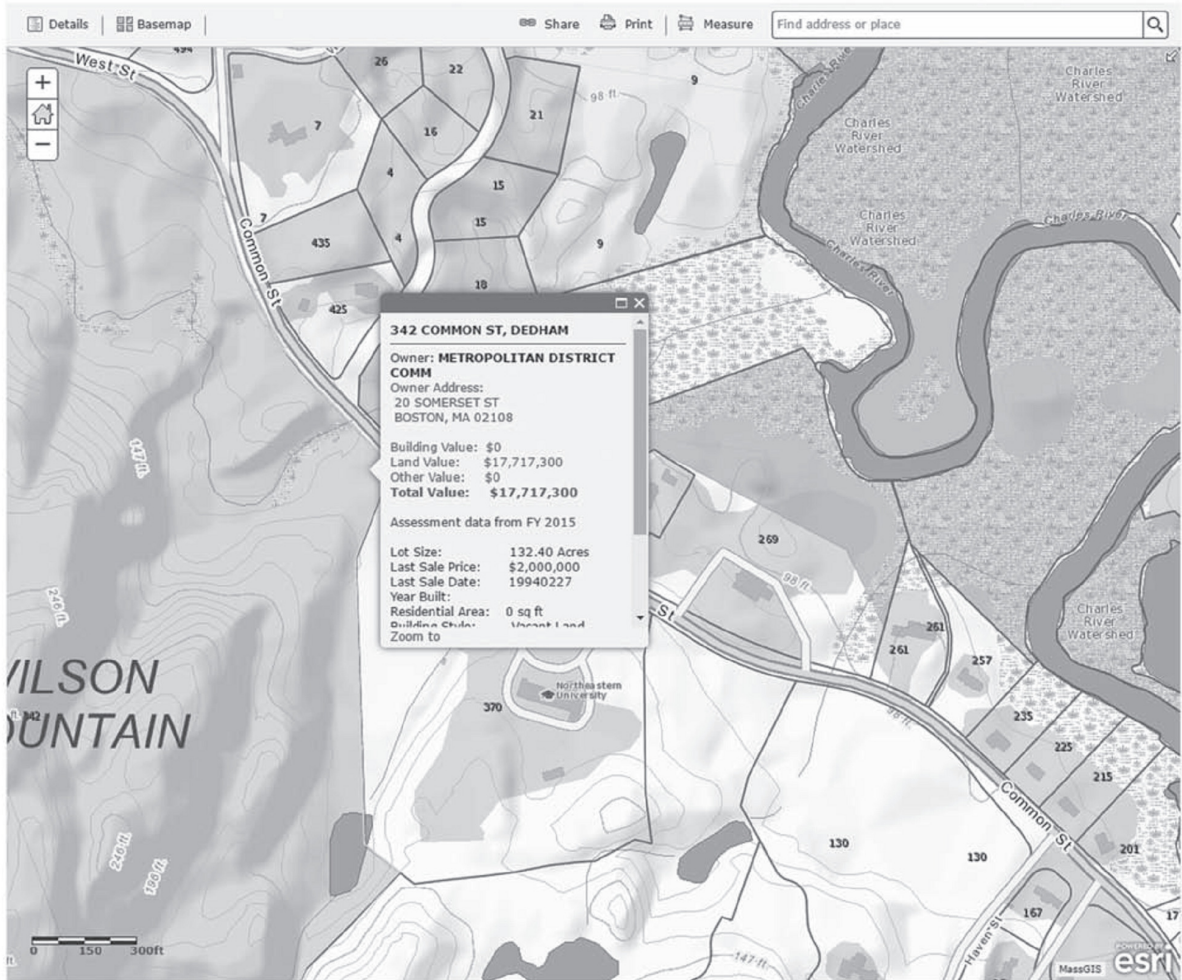


Figure 14–9 A GIS map providing information about property within the Town of Dedham, Massachusetts. (Courtesy of Esri and City of Boston, State of Massachusetts)

Civil Engineering

Civil engineers use GIS to provide a spatial context for efficiently managing infrastructure, such as water and sewer systems, bridges, roads, airports, and solid waste facilities. GIS assists engineers in locating public and private developments by providing information about the potential impacts of the proposed development.

Figure 14–11 shows a GIS map of a portion of the City and County of Honolulu, Hawaii used to display and analyze the location of existing and proposed bike lanes, paths, and routes. In this example, an existing bike path is selected and highlighted in the map, and the path details are shown in the table below the map. Figure 14–12 shows a rendering of a proposed subdivision plat created using a

combination of GIS and CADD technology. Examples of other engineering and public work GIS applications are monitoring pavement conditions, tracking street lighting, siting landfills, and designing transit corridors and planning of new highways.

Demographics

The U.S. Census provides a wealth of geographically referenced socio-economic and demographic data. Governments use this demographic analysis data to support the provision of services. Businesses use census data in daily decision-making processes. GIS programs can use census data to conduct demographic analysis. Figure 14–13 displays a U.S. Census GIS map identifying population and race across the U.S. This example shows the percentage of white people in each U.S. county, with Prima County, Arizona selected. For more information about the U.S. Census, go to www.census.gov.

A department store chain considering a new site can use GIS to analyze the demographics of potential customers in various communities. Employers can track employees within a company by name, address, employment date, and schedule. If the location of each employee's home is associated with a point on a map, then it could be determined which employees are candidates for carpooling or ride sharing. The GIS program can display this information graphically so that employees can see the relationship between their locations and

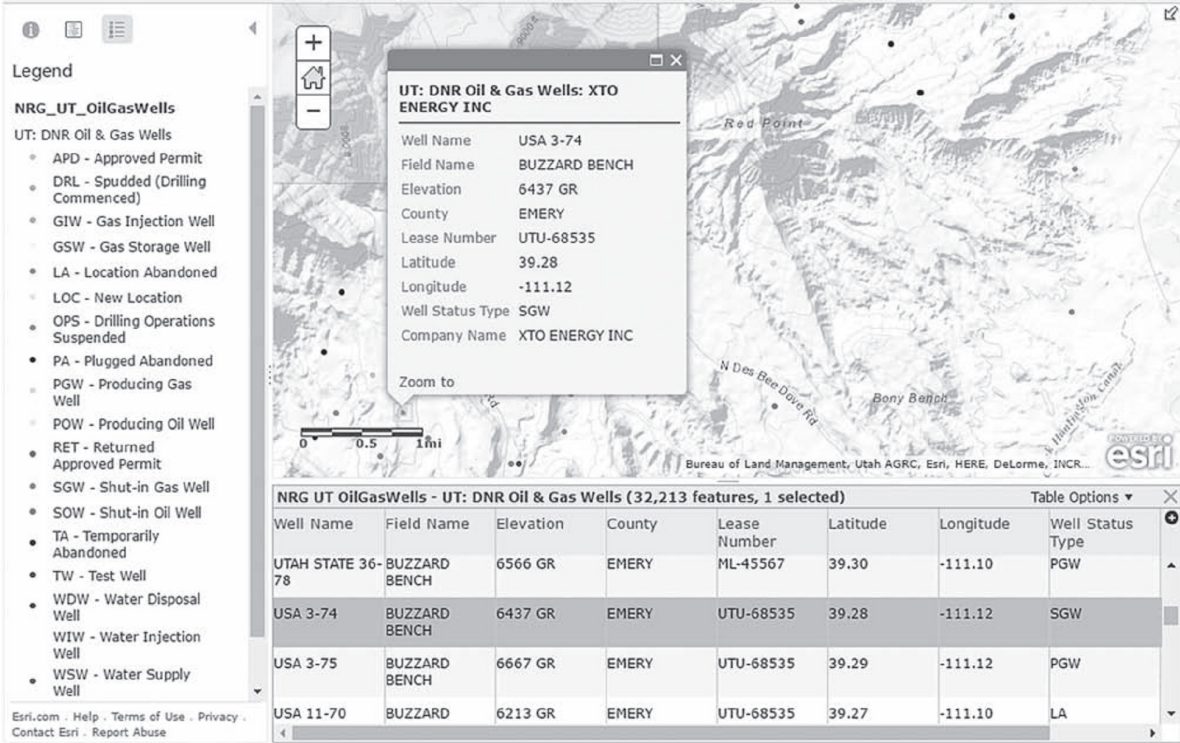


Figure 14–10 A GIS map offering information about oil and gas well surface points across the State of Utah. (Courtesy of Esri and the Utah Department of Natural Resources, Oil and Gas Mining Division)

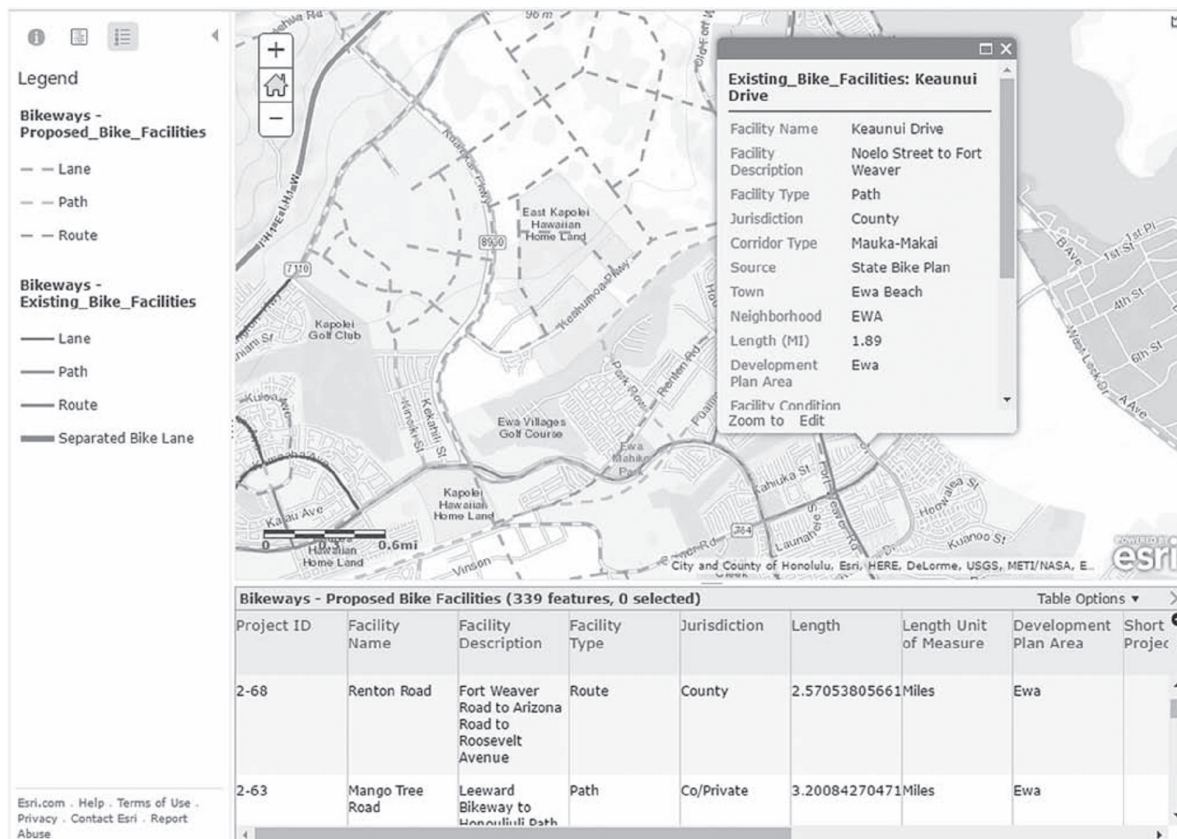


Figure 14-11 A GIS map used to display and analyze the location of existing and proposed bike lanes, paths, and routes in the City and County of Honolulu, Hawaii.

(Courtesy of Esri and the City and County of Honolulu, Oahu, Hawaii)

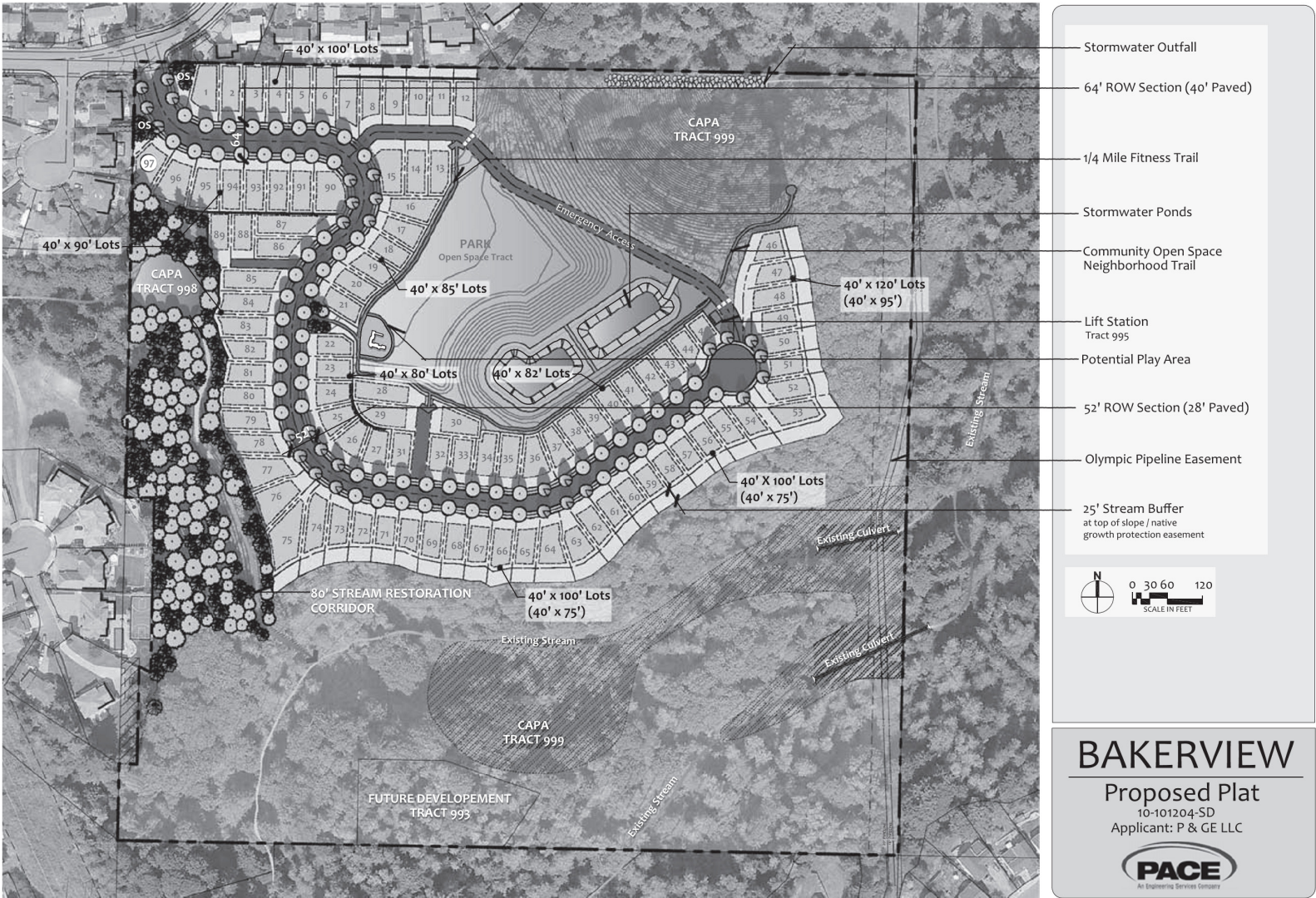
the company's location. Examples of other demographic GIS applications are redistricting, forecasting population and employment, identifying crime patterns, and siting branch locations.

Note: The U.S. Census Bureau offers a variety of maps and geographic data including a major national database of files called the Topologically Integrated Geographic Encoding and Referencing (TIGER) products. TIGER products include all streets and railroads, significant hydrographic features, Native American reservations, military bases, and political boundaries.

Geocoding

Geocoding is the process of displaying a spatial component such as an address, an XY coordinate, or a latitude and longitude, as a geographic location. Geocoding is possible with software and a street-based network that includes attributes describing the address range information within its attribute table for that street segment. Figure 14-14 shows a geocoding service on a mobile device used to find addresses, places, and points of interest.

Figure 14-12 A rendering of a proposed subdivision plat created using a combination of GIS and CADD technology.
(Courtesy of PACE Engineers, Inc.)



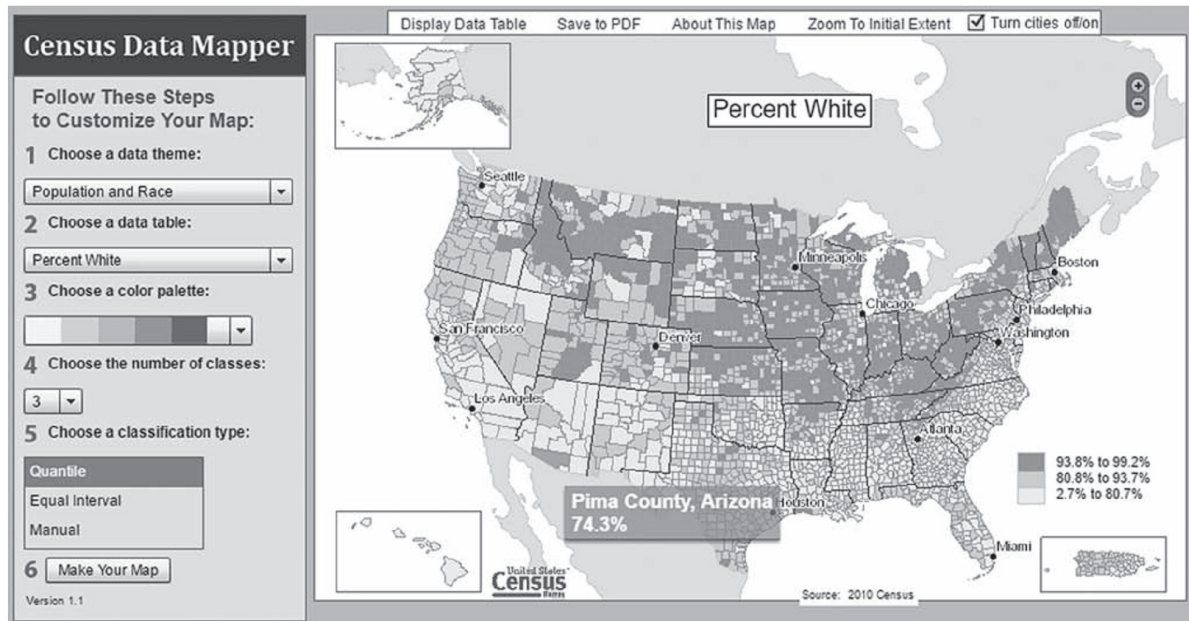


Figure 14–13 A U.S. Census GIS map showing the percentage of white people in each U.S. county, with Pima County, Arizona selected.
(Courtesy of the U.S. Department of Commerce)

Facilities and Utilities Management

GIS technology is commonly used for facilities management and utility system management. Examples of facilities management include siting of transmission facilities, relicensing of hydroelectric projects, routing of meter readers, and tracking of energy use. Figure 14–15 displays a GIS map of the City of Boise, Idaho used to identify the location and details of parks and park facilities. In this example, a recreation/community center is selected with details regarding the facility shown in the map.

Public utilities such as water, wastewater, gas, electric, and telecommunications use GIS in a practice known as automated mapping and facilities management (AM/FM) systems. An electric utility company, for example, can inventory an electrical distribution system to know what customers are affected by downed power lines. Another example is a municipality using GIS to create a hydraulic model of a sewer collection or water distribution system. Drawings, photos, videos, maintenance information, owner's manuals, and other information for different components of the utility system can be linked directly to the features on the maps they apply to, making it much faster to access the information than traditional filing methods.

Modeling

One of the most powerful uses of GIS is modeling. Current applications include modeling of solid waste flow, projection of urban growth patterns, and anticipation of the spread of oil spills. GIS complements other computer-based models that deal with georeferenced data such

Figure 14–14 Using a geocoding service on a mobile device to find addressees, places, and points of interest.

(Courtesy of Esri and
iOSDevelopmentTeam@esri.com)



as economics, transportation, deforestation, and agricultural productivity. GIS provides input data for the model and then displays the model's output. Figure 14–16 shows a GIS map modeling the wildfire hazard potential in the contiguous U.S.

3-D Analysis

3-D models are used within GIS to provide a better representation of certain information and to more realistically analyze terrain on the surface of the Earth. Identifying all locations that can be seen from a specific site is called **viewshed determination**. This can be difficult with traditional map analysis methods but relatively easy and accurate with GIS. Viewing proposed impacts, such as tree harvesting, surface mining, or commercial development, helps avoid mistakes, and provides a means to visualize new developments within the context of the existing environment. 3-D models provide a more realistic way of communicating proposed changes to decision makers, stakeholders, and the public. Figure 14–17 shows a 3-D perspective that illustrates an urban development project scenario in the City of Portland, Oregon.

Related GIS Disciplines

GIS is described as an enabling technology because of the assistance it offers to the many disciplines that use spatial data. A GIS brings these disciplines together by emphasizing analysis, modeling, and

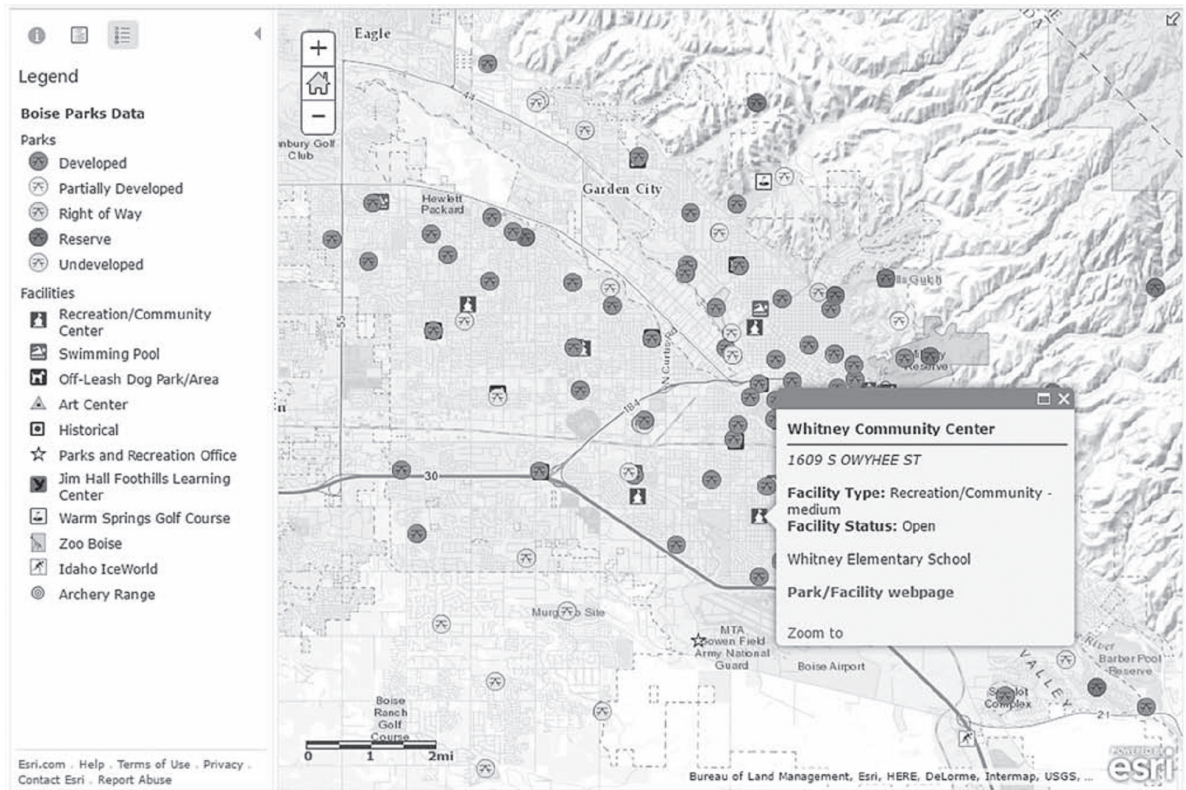


Figure 14-15 A GIS map used to display and evaluate the location and status of parks and park facilities in the City of Boise, Idaho.
 (Courtesy of Esri and the City of Boise, Idaho)

integration. GIS often claims to be the science of spatial information, and it functions as a tool that integrates a variety of data. Each of the following disciplines provides some of the techniques that comprise GIS:

- Geography—Provides techniques for spatial analysis.
- Cartography—Focuses on map design and data display.
- Remote sensing—Provides image analysis and data input.
- Photogrammetry—Calculates measurements from aerial photos.
- Civil engineering—Applies GIS in transportation and urban design.
- Geodesy—Furnishes highly accurate positional control for data.
- Surveying—Supplies positional data on natural and human-made objects.
- Statistics—Provides techniques for data analysis.
- Mathematics—Provides geometry and design theory.
- Project management—Develops, organizes, and coordinates the variety of tasks necessary to complete a project.
- Computer science—May provide any or all of the following: programming for GIS software application development, techniques for hardware and network support, DB administration needed for spatial data management, and methods of data entry and display.

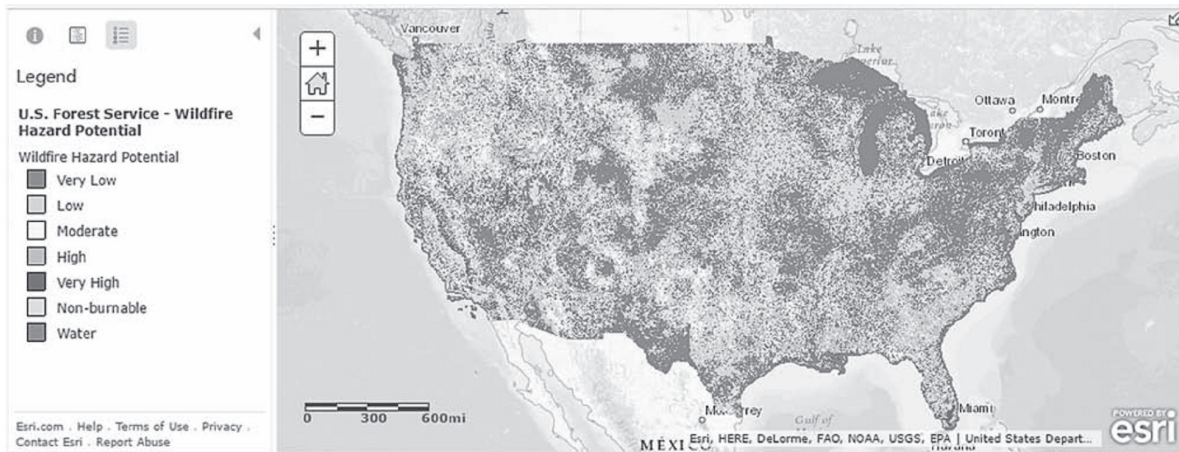


Figure 14-16 A thematic map showing the wildfire hazard potential in the contiguous United States modeled using GIS technology.
(Courtesy of Esri and the U.S. Forest Service)

GIS and CADD

GIS and CADD are complementary technologies. Both systems use a digital data model to enter, store, query, and display information using screen menus and commands. GIS and CADD can both be used to model the world as it exists. The differences between GIS

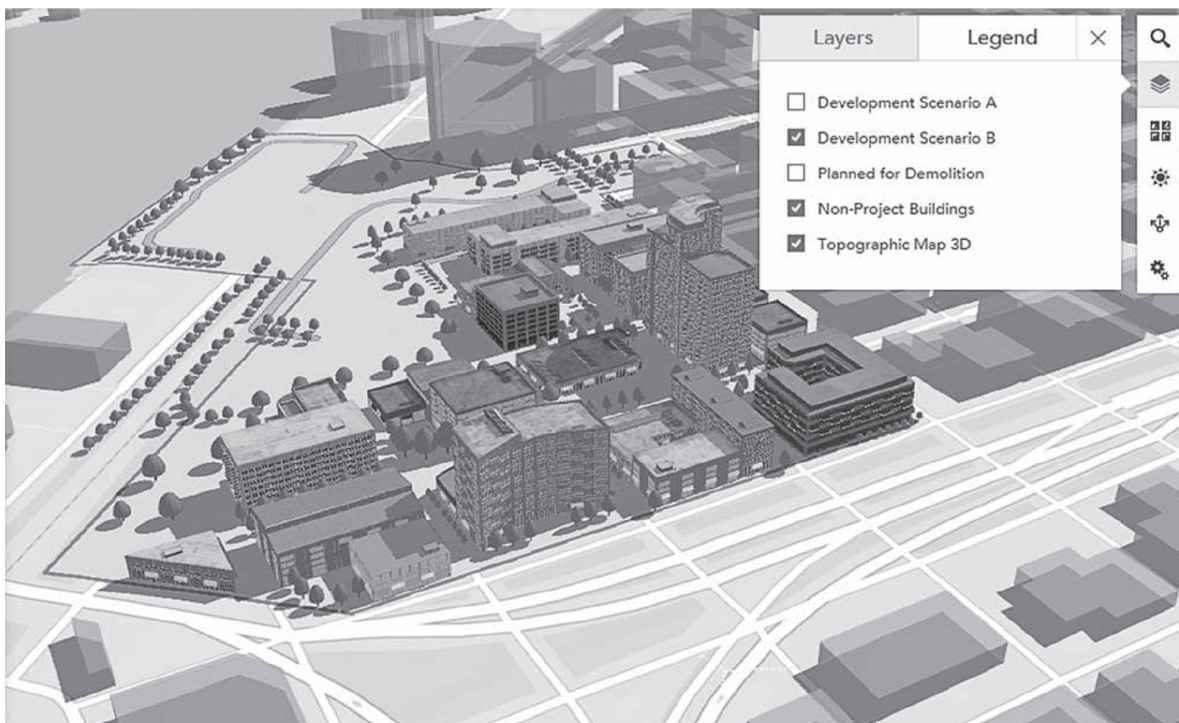


Figure 14-17 A 3-D perspective that illustrates an urban development project scenario in the City of Portland, Oregon.
(Courtesy of Esri and Oregon Metro, City of Portland, State of Oregon)

and CADD are mostly focused on the use of the applications. GIS is principally for thematic mapping and spatial analysis while CADD is used for design and drafting.

GIS data structures make use of topology, while CADD applications use network and polygon topology. GIS has a common organizing principal of location and further organizes data in homogeneous layers generally with a common set of attribute schema, while CADD data structures are optimized for engineering drafting and computational modeling for a specific design or modeling application. GIS data is designed to be aggregated and compared one layer to another independent of a specific design application or modeling calculation. GIS coordinates are typically georeferenced, but can depict a nongeoreferenced space. CADD coordinates can be georeferenced, though often are not, depending on the application.

GIS is a software application designed to help people generate maps to communicate location and descriptions of objects and aggregate information from different data sets. GIS has strong data spatial analytics and cartography tools to assist people in creating maps. CADD is an application that was designed to help people persist geometry for the purpose of generating drawings and aid in the drafting activity. It has strong graphics and geometric manipulation tools. CADD has a strong geometric toolset and a generic Cartesian coordinate system by default. Attributes can be associated with CADD graphics but the relationship between graphics and attributes is less formal than in GIS.

CHAPTER REVIEW

Answer the following questions using the information presented in this chapter.

- 14-1** Define GIS.
- 14-2** What is spatial data?
- 14-3** List four different commercial GIS software products.
- 14-4** Explain how a GIS map uses layers.
- 14-5** What are the three primary feature types that GIS programs store as spatial data?
- 14-6** Name two examples each of point, line, and polygon spatial features.
- 14-7** What type of database management system is used by GIS software?
- 14-8** Describe the feature name and type characteristics of a GIS database.
- 14-9** Describe the feature attribute and geographical position characteristics of a GIS database.
- 14-10** Describe how a raster GIS stores data. Give three examples of the types of features where the raster format works best.
- 14-11** Describe two advantages of a vector GIS. Give three examples of the types of features where the vector format works best.
- 14-12** Describe two disadvantages of a raster GIS.

- 14-13** What is the term for conversion of vector data to raster data?
- 14-14** What is the type of analysis that topology permits?
- 14-15** Fill in the blank: _____ permits synthesis and data display in new and creative ways, using spatial and attribute queries.
- 14-16** Describe three types of spatial queries.
- 14-17** Give four examples of spatial data that civil engineers regularly use.
- 14-18** Describe two common GIS applications.
- 14-19** Why is GIS considered an enabling technology?
- 14-20** Explain the main differences between GIS and CADD.

PROBLEMS

Follow the specific instructions to complete each problem.

- P14-1** Research and write a report of approximately 250 words describing a GIS software product.
- P14-2** Research and write a report of approximately 250 words describing the employment opportunities for civil drafters in the city and state in which you live.
- P14-3** Describe four GIS applications and provide a GIS map to illustrate each application. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.

- P14-4** Research and write a report of approximately 250 words describing a specific GIS application. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.
- P14-5** Show a soil map in raster GIS format with at least three different soil types.
- P14-6** Interview a GIS professional at a local municipality or civil engineering company to learn more about GIS, including a description of the skills required to be a GIS technician, the most common types of GIS maps created by the technician, and a typical day as a GIS technician. Write a report of approximately 250 words covering what you learn. Prepare a PowerPoint presentation of your research and present the slide show to your class or office.
- P14-7** Complete a GIS course or program at a local technical school, community college, or university.

Glossary

- 3-D chain** A three-dimensional (3-D) path in AutoCAD Civil 3D that a typical road section can be extruded along.
- 3-D laser scanner** A device that uses a laser light beam to measure distances.
- 3-D laser scanning** The method of collecting detailed three-dimensional (3-D) information using a laser scanner that passes a laser over the surface of an object or area.
- Acute angle** An angle less than 90° .
- Aerial laser scanning** See Airborne laser scanning.
- Aeronautical chart** A map used to aid air travel.
- Aerotriangulation** The method of associating aerial photographs to known ground control points.
- Aerial photographs** Photos taken at various altitudes and controlled by base stations at known distances on the ground to check for accuracy.
- Airborne laser scanning (ALS)** A three-dimensional (3-D) laser scanning technology that uses a laser scanner, typically with multiple laser sensors and digital cameras with global navigation satellite system (GNSS) receivers and inertial measurement units (IMUs), attached to an aircraft or spacecraft.
- Alignment** A term used in mapping, civil engineering, and surveying to describe the horizontal or vertical characteristics of a route such as a road, highway, railway, or utility line.
- All-weather** A gravel or paved surface.
- Angle of repose** The steepest slope at which a specific material is stable.
- Angle** The amount of space, or turn, between two lines, known as arms or sides, that intersect at a point known as the vertex.
- Area feature** See Polygon feature.
- As-built drawing** A drawing drawn after a construction project is finished to document final construction.
- As-built** See As-built drawing.
- As-built survey** A survey performed after a construction project is finished to identify final construction, including improvements and structures created during construction.
- Assembly** An AutoCAD Civil 3D template.
- Attributes** Text-based data assigned to a specific object.
- Average end method** A method that uses the averages of the two end cross sections to compute the volume of Earth between the sections.
- Azimuth** A horizontal angle measured in a full circle from a reference line, generally north–south, in a clockwise direction.
- Back tangent** The tangent line before the beginning of a curve.
- Backsight (BS)** The rod or target location in surveying from which a reference measurement is made.
- Base station** A Global Positioning System (GPS) receiver positioned at a known, fixed location.

Baseline (1) The east–west parallel of the public land survey system. (2) The line between two transit stations.

Bearing The direction of a line with respect to one of the quadrants of the compass.

Bench mark (BM) A survey mark intended to be permanent that specifies the latitude, longitude, and elevation of a point.

Border Lines that create the format margins of the sheet.

Borrow pit An excavation from which material is removed and used as fill elsewhere.

Boundary survey See Land survey.

Bounds Boundaries, such as streams, streets, roads, or adjoining properties.

Breaking chain A process of taking multiple tape measurements, often used on a slope.

Breakline A line that defines a change in slope such as a ridge line, the edge of pavement, or a ditch line.

Buffering A spatial analysis that creates new polygons around a set of points, lines, or other polygons.

Building information modeling (BIM) A unified sequence of processes through which a project passes from initiation to operation.

Cadastral map A large-scale map that accurately shows property boundaries and public lands.

Cadastral survey See Land survey.

Cartesian coordinate system A coordinate system that locates points in three-dimensional (3-D) space according to distances from intersecting X, Y, and Z axes.

Cartographer A highly skilled professional who designs and draws maps.

Cartography The art of making maps and charts.

Catch basin A storm sewer inlet designed to collect runoff and trap debris that would otherwise flow into the sewer pipe.

Central angle See Delta angle(Δ).

Cesspool A tank designed to break down and distribute waste materials to an area of Earth.

Chaining See Taping.

Chart The name commonly assigned to some maps, such as aeronautical and nautical charts.

Chord A linear distance between two points on a circle or arc.

Circular curve See Simple curve.

Civil drafting Drafting performed for civil engineering.

Civil engineering The branch of engineering related to the planning, design, construction, and maintenance of structures.

Client The individual or organization for which a project is developed.

Closed traverse A series of lines that return to a point of beginning or close on a different known control point.

Code A standard that one or more governmental bodies adopts and has the force of law.

Code of ethics A formal document that states an organization's values and the rules and principles that employees are expected to follow.

Collar See Margin.

Combined sewerage outlet (CSO) Storm sewage processed with domestic sewage.

Compound curve Two simple curves with different radii joined together and curving in the same direction.

Computer-aided design and drafting (CADD) The process of using a computer with CADD software to design and produce drawings and models according to specific industry and company standards.

- Concrete block** A rectangular masonry construction unit.
- Concrete masonry unit (CMU)** *See* Concrete block.
- Connecting traverse** A closed traverse that begins and ends at known points.
- Construction survey** A survey performed at a construction site to locate the points and specify the elevations needed during the construction of structures.
- Consulting engineering** An independent service that provides licensed and certified engineering for construction and related projects.
- Contour interval** The vertical elevation difference between contour lines.
- Contour line** A line that connects points of equal elevation.
- Control point survey** One method of establishing elevations for use in contour mapping.
- Control survey** A survey that establishes control points with accurate horizontal and/or vertical positions.
- Coordinate geometry (COGO)** A means used in computer-aided design and drafting (CADD) systems for laying out survey data.
- Coordinate system** A method that uses numbers, or coordinates, to specify the location of points in space.
- Corner cube prism** A corner cut off of a cube of glass.
- Corridor** A system in AutoCAD Civil 3D that dynamically responds to changes in the alignment, profile, configuration of the template, and/or formation of the existing ground surface.
- Crawler dozer** A tracked machine that uses a front-mounted blade to move material, such as dirt.
- Credit legend** A component of a map that provides a variety of information about the mapping and geodetic control agencies, and how the map was created.
- Crest curve** A vertical curve that changes the vertical alignment of a road from uphill to level or uphill to downhill.
- Cross section** *See* Cross section view.
- Cross section view** A view that cuts through an area to show detail that cannot be clearly identified in plan view.
- Culture symbols** Symbols that represent works of people.
- Curve length** *See* Length of curve (L).
- Cut and fill** A term used in construction to describe the method of cutting, or removing by excavating, material from a location to use to fill, or add, material to a different location.
- Cutting-plane line** A line drawn on a plan view to show the location of a cross section cut.
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- Database (DB)** An electronic filing system that provides a collection of information organized for a computer program to rapidly select desired pieces of data.
- Database management system (DBMS)** A collection of programs that let you store, modify, and extract information from a database.
- Datum** A theoretically exact reference point, axis, or plane.
- Daylight line** The longitudinal line connecting all of the daylight points.
- Daylighting** The function of seeking out and intersecting with existing ground.
- Deflection angle** An angle that veers to the right or left of a straight line.
- Degree** A unit of angular measurement. There are 360° in a complete circle.
- Degree of curve (D)** The angle of the 100' (30 m) arc or chord that connects station points.

Delta angle (Δ) (1) The angle of a curve formed by two radii from the center point of the arc (O) to the point of curve (PC) and point of tangency (PT). (2) The angle formed between the vertex and the two sides.

Delta note Specific note placed with general notes and keyed to the drawing with a symbol.

Denominator The number below the fraction bar.

Desktop GIS A system that uses software loaded on your desktop computer to process geographic information system (GIS).

Detail drawing A typically enlarged view created to describe features not shown on other drawings.

Detail reference symbol A symbol with cross-reference information drawn on a view, such as a plan view, to show the location of a detail and help key the plan view to the detail in a set of drawings.

Detail See Detail drawing.

Detail view A drawing view that can be used to display and dimension a portion of another view that has detail that cannot be clearly shown due to the drawing scale or complexity.

Differential correction See Differential GPS.

Differential GPS The process of using two Global Positioning System (GPS) receivers and mathematically comparing the satellite information collected from both receivers.

Differential leveling The method used to determine the difference in elevation between two points.

Digital elevation model (DEM) A raster image model created from a collection of three-dimensional (3-D) points showing bare surfaces of land, without natural vegetation and built structures.

Digital terrain model (DTM) A vector graphic model created from a collection of three-dimensional (3-D) points showing terrain and features that define a change in slope such as a stream or ridge, or the edge of a wall or road.

Digital surface model (DSM) A raster image model that shows land with natural and built surface features such as vegetation and structures.

Dimensions Items that describe the size, shape, or location of features on an object or structure.

Direct leveling The theory of measuring vertical distances relative to a horizontal line, and using the measurements to calculate the differences between the elevations of points.

Direction The angular relationship of one line to another.

Divider See Mechanical divider.

Domestic sewage The wastewater from toilets, bathtubs, showers, laundry, and kitchen.

Drainfield See Soil absorption field.

Drawing content All of the objects, settings, and other components that make up a drawing.

Drawing template A file that includes drawing settings and objects for specific applications that are preset each time you begin a new drawing.

Drone See Unmanned aerial vehicle.

Earthwork A term used in construction to describe quantities of Earth excavated from or filled into areas.

Easement A legal right-of-way given by a property owner to allow others access to or over the property.

East longitude Meridians west of the prime meridian.

Effluent Wastewater from a septic tank or cesspool.

Electronic distance measuring instrument (EDMI) A device that measures distance using electromagnetic or microwave radio waves, or infrared or laser light waves.

Electronic distance meter (EDM) See Electronic distance measuring instrument (EDMI).

Elevation The height of a geographic location above or below a theoretically exact reference point, axis, or plane.

Engineer's scale A decimal U.S. customary (inch) scale calibrated in multiples of 10.

Engineering map A map that details the layout of an engineering project such as a building construction project.

Ergonomics The science of adapting the work environment to suit the needs of the worker.

Erosion control A practice designed to prevent or control wind or water erosion during land use, development, and construction activities.

Error of closure The distance between the true and calculated position of the same point.

Ethics Rules and principles that define right and wrong conduct.

Exporting The process of transferring electronic data from a database, such as a drawing file, to a different format used by another program.

External distance (E) The distance from the point of intersection (PI) to the midpoint of the curve, and bisects the interior angle at the PI.

Extracting Reselecting a subset from existing features.

Feature lines Longitudinal connectors in AutoCAD Civil 3D that can serve as breaklines.

Field Any open area that surrounds the main views displayed on the drawing.

Field notes Recorded observations such as measurements, instrument readings, and calculations made by surveyors in the field.

Firebreak An area with ground cover no more than 24" in height, with all dead vegetation removed.

Floating viewport An AutoCAD viewport added to a layout in paper space to display objects drawn in model space.

Font The face design of a letter or number.

Footing The lowest member of the foundation system used to spread the loads of the structure across supporting soil.

Footplate A cone-shaped device that has pointed feet anchored in the ground.

Foresight (FS) The rod or target location in surveying to which an elevation and/or location reading is taken.

Forward tangent The tangent line after the end of the curve.

Full angle An angle equal to 360° or 2π radians.

Full station A station point at a 100' (30 m) increment.

General discipline notes Notes that reflect information about specific disciplines, such as sewer, water, or other utilities.

General notes Notes that apply to an entire drawing.

General sheet notes Notes that provide information about the sheet or sheets in a set of drawings.

Generalizing Combining polygon features based on similar attributes.

Geocentric datum A datum that specifies the center of the Earth at the Earth's center of mass.

Geocoding The process of displaying a spatial component such as an address, an XY coordinate, or a latitude and longitude, as a geographic location.

Geodesy The science of measuring the size and shape of the Earth, and the location of points on the Earth's surface.

Geodetic datum A system associated with a reference surface used to provide known locations.

Geodetic survey A survey that factors in the curvature of the Earth.

Geographic coordinate system A coordinate system that establishes the location of points on the Earth using the degrees of a circle as reference.

Geographic information system (GIS) An electronic system used to collect, manage, analyze, and present spatial and attribute data.

Geographic meridian *See* True north.

Geographic north *See* True north.

Geologic map A map that describes the location, type, and extent of geologic features such as rock formations and edges of Earth movement.

Geomatics The whole method of collecting, storing, managing, and presenting geographic or spatial data.

Georeferenced image The result of associating objects with locations on the Earth using a geodetic or other coordinate system.

Georelational data model Spatial and attribute data related by a common item that has a unique value.

Girder A horizontal structural member that spans between two or more supports.

Global navigation satellite system (GNSS) A generic term for any system of satellites that provide global coverage for geographic positioning.

Global Positioning System (GPS) The United States global navigation satellite system (GNSS) which uses a network of satellites in combination with Earth-based receivers to determine locations on the Earth.

Grade (GR or GRD) An established elevation such as site or road grade.

Grading plan A construction drawing that generally shows existing and proposed topography.

Grading The process of building a specific slope or level surface.

Graphic pattern A patterned arrangement of objects or symbols.

Graphic scale A symbol, located in the field, legend, or margin of a sheet, with a system of ordered marks at fixed intervals used for measurement.

Graphic symbols legend A legend that identifies symbols found on a drawing.

Great circular arc An arc with its center coinciding with the center of the sphere.

Grid azimuth Direction established for a rectangular survey system so that the north–south grids of the survey are used as the reference, or zero line.

Grid north (GN) The north–south lines of a grid mapping system such as the Universal Transverse Mercator (UTM) and the State Plane Coordinate (SPC).

Hard copy A physical drawing created on paper or some other media by a printer or plotter.

Height of the instrument (HI) The backsight reading is added to the elevation of the known point to determine the height of the level.

High-resolution surveying *See* Stationary ground-based laser scanning.

Horizontal alignment The position and direction of a route on a horizontal plane, or plan view.

Horizontal curve A geometric feature that occurs when a route changes direction or alignment.

Hydraulic survey A hydrographic survey used to determine the design characteristics of hydraulic structures, such as bridges, culverts, dams, and docks.

Hydrographic survey A survey that accurately locates and measures the boundaries and characteristics of surface waters, or hydrography.

Hypermedia A system for referencing and retrieving different forms of digital data.

Included angle See Delta angle(Δ).

Index contour Every fifth contour line on a topographic map.

Inertial measurement unit (IMU) A device that measures linear acceleration and angular rotation using three gyroscopes and three accelerometers.

Infrastructure The structures, facilities, and services required for an economy to function such as buildings, roads and bridges, water supply and sewer systems, and power supply and telecommunication systems.

Insertion base point The point on a symbol that defines where the symbol is positioned during insertion.

Intellectual property The products of a company that are often the result of years of research, engineering, and development.

Intermediate contours The four contour lines between index contours.

Intermediate foresight (IFS) A separate elevation taken in addition to the run of levels for information purposes.

Interpolation The process of inserting missing values between given numbers.

Intersecting angle (I) The exterior deflection angle at the point of intersection (PI), between the back tangent and the forward tangent.

Invert elevation (IE) The elevation at the bottom inside of a pipe.

Key note See Delta note.

Key See Legend.

Land survey A survey that locates property corners and boundary lines.

Land use planning The organized evaluation of physical, social, and economic land issues in a way that supports land users in making decisions that increase their productivity and sustainability, and meets the needs of society.

Laser detector A device used to detect the beam from a laser level when the beam cannot be seen, such as over far distances or in bright light.

Laser receiver See Laser detector.

Layer A logical grouping of data.

Layout See Paper space.

Leach lines See Soil absorption field.

Left-hand curve A curve with a deflection angle to the left.

Legend A graphic that explains the symbols, colors, and labels that make up the map or drawing data.

Length of curve (L) The centerline distance along the arc from the point of curve (PC) to the point of tangency (PT).

Level cross section A cross section in which the ground is basically level, and the height, or depth, of the cut is constant across the profile.

Level pole See Level rod.

Level rod A rod graduated to fractions of feet or meters used to measure elevations and distances when viewed through a level or transit.

Level staff *See* Level rod.

Leveling The process of determining the difference in elevations between points.

Library files Files that include standard content used for many different projects, such as border, title block, and detail files.

Light Detection and Ranging (LiDAR) *See* 3-D laser scanning.

Light-frame construction *See* Wood-frame construction.

Limits The dimension of the virtual drawing area.

Line conventions The standards related to line weight, type, color, and purpose.

Line feature A series of geographic coordinate points joined together to form a curve, such as a stream, road or railway centerline, power line, sewer line, or contour line.

Line laser level A laser level that projects a laser beam or beams in front of the instrument that appears on a surface as a line or crosshairs.

Line thickness *See* Line weight.

Line weight The assigned width of lines for display and plotting.

Line work The placement and correct use of lines, shapes, and symbols on a drawing.

Lines of latitude Imaginary parallel lines that circle the Earth horizontally.

Lines of longitude Imaginary lines that circle the Earth vertically, and pass through the north and south poles.

Local attraction Any local influence that causes the magnetic needle to deflect away from the magnetic meridian.

Local control points Semi-permanent points established by surveyors.

Local notes *See* Specific notes.

Location A geographic point or area.

Long chord (LC) The chord distance from the point of curve (PC) to the point of tangency (PT).

Loop traverse A closed traverse that closes on the point of beginning.

Lot An individual piece of property.

Lot and block A method of describing land by referring to a recorded plat, the lot number, the county, and the state.

Low impact development (LID) Techniques for managing storm water using systems modeled after nature, such as rain gardens, vegetated swales, porous pavement, and storm water planters.

Low impact development approach (LIDA) *See* Low impact development (LID).

Machine control The process of guiding heavy earthmoving equipment on a construction site.

Magnetic azimuth A horizontal angle measured using magnetic north as the reference line.

Magnetic compass *See* Magnetic north.

Magnetic declination (MD) The horizontal angle between the magnetic meridian and the true meridian, at any point.

Magnetic meridian *See* Magnetic north.

Magnetic north (MN) The direction where the compass north arrow points.

Maintenance hole *See* Manhole.

Major contour *See* Index contour.

Manhole An underground structure used for maintenance access or for making connections to underground utilities and other services, including sewers, telephone, electricity, storm drains, and gas.

Manhole cover A metal or concrete cover designed to prevent accidental or unauthorized access to the manhole.

Manual drawing Drafting done using traditional tools to create drawings by hand with pencil or ink on paper or other media.

Map A graphic representation of part or all of Earth's surface, drawn to scale on a plane surface.

Map coordinate system A rectangular grid designed to simplify the creation and use of maps by specifying locations using XY coordinates.

Map projections The geometric methods of projecting the Earth's surface onto a flat map.

Margin The area around the body of a quadrangle map that displays information about the map such as the title, scale, location references, map projection, and coordinate system.

MasterFormat A list of numbers and titles that is created for the organization of information into a standard sequence that relates to construction requirements, products, and activities.

Material take off (MTO) *See* Quantity take off (QTO).

Mean sea level (MSL) The average of high and low tides taken by a tide gage over an extended period of time.

Measuring wheel A device that measures and records distance as a wheel is rolled along the ground.

Mechanical divider A drafting instrument consisting of two pointed legs, pivoted together at one end and used for transferring distances.

Meridian (1) A fixed line designated as having zero direction. (2) *See* Lines of longitude.

Metes and bounds A method of describing and locating property by measuring the length and bearings of property lines from a known starting point called a monument.

Metes Measurements of features such as property lines expressed in units of feet, yards, rods, or meters.

Metric scale A decimal International System of Units (SI) scale calibrated in multiples of 10.

Middle ordinate (M) The distance from the midpoint of the curve to the midpoint of the loop chord (LC).

Mil *See* Milliradian.

Military map A map that displays information of military importance or that serve a military use.

Milliradian (mil) A unit of angular measurement approximately equal to 1/6,400 of the circumference of a circle.

Minor contours *See* Intermediate contours.

Mobile GIS An app that allows you to access geographic information system (GIS) data and functionality on your mobile device, and is often used to collect and analyze data in the field.

Mobile ground-based laser scanning A three-dimensional (3-D) laser scanning technology that uses a laser scanner, typically with multiple laser sensors, and odometers, wheel and internal sensors, and digital cameras with global navigation satellite system (GNSS) receivers, attached to a moving vehicle such as a car, truck, railcar, or all-terrain vehicle (ATV).

Mobile laser scanning (MLS) *See* Mobile ground-based laser scanning.

Mobile mapping *See* Mobile ground-based laser scanning.

Mobile terrestrial laser scanning *See* Mobile ground-based laser scanning.

Model A two-dimensional (2-D) or three-dimensional (3-D) design composed of objects created at full scale.

Model file A file that contains the full scale drawing or model with individual elements that make up the design, such as the property lines, buildings, utilities, and roadways on a site plan.

Model space The AutoCAD environment in which you create drawings and designs at full scale.

Monument A fixed point such as a section corner, a rock, a tree, or an intersection of streets.

Natural resources management The sustainable use of natural resources, such as land, air, water, minerals, plants, and animals.

Nautical chart A map used to aid to water navigation.

Nearest-neighbor A spatial analysis that identifies features that are closest to another feature.

Negative departures The distance a line extends in a west direction.

Negative latitude The latitude of a line that extends in a southerly direction.

Network analysis A spatial analysis that performs flow analysis, determines routing, or orders stops.

North latitude Parallels north of the equator.

Numerator The number above the fraction bar.

Numerical scale Specifies the proportion between the length of a line on a map and the corresponding length on the Earth's surface, known as the representative fraction (RF).

Oblate spheroid (1) A flattened three-dimensional (3-D) ellipse, or ellipsoid, that rotates around the minor axis. (2) An ellipsoid that contains two centers of equal radius, rotated around the minor axis.

Obtuse angle An angle between 90° and 180°.

Odometer A device used to measure and record distance.

Open source application A program that you can use and modify for free.

Open traverse A series of lines that do not return to a point of beginning and do not necessarily begin or end at control points.

Optical-micrometer level A level that employs a special lens that can be rotated to vertically deflect the incoming light ray from the line of sight.

Ordinate The tangent distance from the top of the curve to the grade tangent line at each horizontal station point.

Origin The point where the *X*, *Y*, and *Z* axes intersect, or 0,0,0.

Pacing A way to measure distance by walking and counting the number of steps taken.

Paper space The AutoCAD environment in which you prepare the final drawing for plotting to scale.

Parallels of latitude See Lines of latitude.

Parallels See Lines of latitude.

Parameter A geometric characteristic and dimension that controls the size, shape, and position of geometry.

Pedometer An instrument that estimates the distance traveled by walking and records the number of steps taken.

Percent grade See Percent slope (S).

Percent slope (S) A slope value equal to (vertical rise ÷ horizontal run) × 100.

Perpendicular Lines that intersect at a 90° angle.

Photogrammetric map A map created from photographs, typically aerial photographs, using photogrammetry.

Photogrammetric survey A survey conducted from photographs, typically aerial photographs, using photogrammetry.

Photogrammetry The method of measuring the distance between points on photographs.

Physical map A map that displays the physical features of an area such as differences in elevation and bodies of water.

Pictorial view A view showing an object in three-dimensional (3-D) picture.

Pipe laser level A laser level that projects a laser beam in front of the instrument that appears on a surface as a dot.

Plan and profile A type of drawing that combines the plan view of a project, or often a specific portion of a project, with the corresponding profile of the plan below.

Plan See Plan view.

Plan view A view of an area looking down on the area as projected onto a horizontal plane.

Plane A flat surface.

Plane survey A survey conducted as if the Earth were flat, without factoring in the curvature of the Earth.

Planned unit development (PUD) See Planned use development.

Planned use development A development that allows zoning with mixed uses such as single- and multifamily homes, parks, schools, offices, small businesses, restaurants, and grocery stores.

Planning map A map that depicts the layout and characteristics of an area for municipal planning purposes.

Plat See Site plan.

Plot (1) To draw. (2) See Site plan.

Plot device The printer, plotter, or alternative plotting system to which the drawing is sent.

Plot plan See Site plan.

Plumb bob A weight hanging from a string used to establish a vertical line to a point.

Plumb laser level A laser level that projects a beam in front of the instrument that appears on a surface as a dot.

Plunged When a survey instrument is flipped, or turned over on its transverse axis.

Plus station A point between full stations.

Point cloud A mass of three-dimensional (3-D) XYZ coordinate point data.

Point feature An item at a single geographic coordinate point such as a tree, survey marker, power pole, manhole, well, or destination.

Point of curvature See Point of curve (PC).

Point of curve (PC) The point where a curve begins.

Point of intersection (PI) The point where the back and forward tangent extensions intersect.

Point of reverse curve (PRC) The point at which one curve ends and the next curve of a reverse curve begins.

Point of tangency (PT) The point at the end of a curve where the curve is tangent to the forward tangent.

Point-in-polygon A spatial analysis that locates points that are within polygons.

Political map A map that shows the boundaries of governments such as countries, states, and counties.

Polygon A closed geometric figure with three or more sides.

Polygon feature A series of geographic coordinate points joined together to form a boundary such as a specific type of soil or forest, a parcel of land, urban area, or census tract.

- Polygon overlay** A spatial analysis that generates new polygons from two or more existing polygons.
- Positive departure** The distance a line extends in an easterly direction.
- Positive latitude** The latitude of a line that extends in a northerly direction.
- Potable water** Water that is safe to drink.
- Poured-in-place concrete** The construction method of pouring unhardened concrete into forms built at the construction site according to the specified size, shape, and location of foundations, floors, walls, columns, beams, and other members.
- Precast concrete** The construction method of forming concrete components off-site at a fabrication plant and transporting the components to the construction site for assembly.
- Prime meridian** The imaginary line connecting the north and south poles, and passing through Greenwich, England.
- Principal meridian** The north-south meridian perpendicular to the baseline in the public land survey system.
- Professional engineer (PE)** An engineer who has a four-year degree in engineering from an accredited engineering program, has passed the Fundamentals of Engineering (FE) exam, has completed four years of progressive engineering experience under a PE, and has passed the Principles and Practice of Engineering (PE) exam.
- Profile** A cross section of a portion of land, or along the length of a linear feature such as a road, sewer line, power line, or stream.
- Profile leveling** A leveling technique similar to standard differential leveling but additional intermediate shots are taken along the centerline of the route.
- Project files** Files that apply to individual projects, and are categorized as model, detail, sheet, schedule, text, database, symbols, border, and title block files.
- Project map** A map that shows a construction site in relationship to the immediately surrounding area.
- Prolongation of the line** The preceding line of a survey extended beyond the current station point.
- Property survey** See Land survey.
- Public Land Survey System (PLSS)** A rectangular system for describing land in the United States, developed by the U.S. Bureau of Land Management (BLM).
- Public utility easement (PUE)** See Utility easement.
- Quadrangle map** A map of an area of the Earth's surface with a grid showing geographic location.
- Quantities** The elevations of the corners of a face on a surface.
- Quantity take off (QTO)** A list, or the process of generating a list, of materials and other information such as the quantities and weights of materials required for a construction project.
- Query** A question that allows you to find the desired information in the database.
- Radian** An angular unit of measure in which 2π radians = 360° and π radians = 180° .
- Radiation** Survey in which measurements are taken from a survey instrument located at a central point called a transit station.
- Radius (R)** The radius of the circle of which the curve is an arc.
- Ranges** The vertical columns east and west from the principal meridian.
- Rasterization** The conversion of vector data to raster.

Rear tangent See Back tangent.

Rectangular coordinate system A coordinate system in two-dimensional (2-D) drafting divided into four quadrants on the *XY* plane by the *X* and *Y* axes.

Reflex angle An angle between 180° and 360°.

Region feature A set of overlapping or separate polygons.

Regular polygon A closed geometric figure with three or more equal sides and equal angles.

Reinforced concrete Concrete poured around steel bars called rebar, or other steel reinforcement placed in the forms.

Relief symbols Symbols used to show characteristics of land such as mountains and canyons.

Remote sensing The detection of information about an object or experience, without actually contacting the object or experience.

Representative fraction (RF) The distance on a map ÷ the distance on the Earth (RF = distance on map/distance on the Earth), using the same units of measure.

Reverse curve Two simple curves with the same or different radii joined together and curving in opposite directions.

Ridge A long narrow area of ground at higher elevation.

Right angle An angle equal to 90° or $\pi/2$ radians.

Right-hand curve A curve with a deflection angle to the right.

Rotating beam laser level A laser level that projects a 360° rotating laser beam in a plane.

Rotating laser level See Rotating beam laser level.

Route feature A linear feature used by the transportation industry.

Route survey A survey that provides accurate location and elevation data of natural and human-made features along a route, such as a road, highway, railroad, or pipeline.

Rover A Global Positioning System (GPS) receiver used to collect data at unknown points.

Saddle A low spot between two peaks.

Sag curve A vertical curve that changes the vertical alignment of a road from downhill to level or downhill to uphill.

Sanitary sewer A system of underground pipes that transports domestic sewage to a treatment plant where the wastewater is cleaned and discharged.

Satellite constellation A network, or group, of satellites.

Scale (1) The ratio of measuring units expressing a proportional relationship between a drawing and the full-size items the drawing represents. (2) An instrument with a system of ordered marks at fixed intervals used for measurement.

Scale bar See Graphic scale.

Scale factor The reciprocal of the drawing scale, and is used in the proper scaling of various objects such as text, dimensions, and graphic patterns.

Schedule A grouping of related items with corresponding distinguishing features and headings, and a minimum of three columns of related information.

Section A parcel of land, approximately 1 sq. mi., containing 640 acres. There are 43,560 sq. ft. in an acre.

Selective availability (SA) The intentional degradation of Global Positioning System (GPS) signals.

Self-reading rods Rods that can be read by the person operating the instrument.

Septic tank A tank designed to hold domestic sewage for two or three days, which is long enough for most heavy, suspended material to sink to the bottom of the tank.

Server GIS An evolution of desktop geographic information system (GIS) that allows you to access GIS data and functionality through networks, known as geoprocessing.

Setbacks Imaginary boundaries beyond which the structure cannot be placed.

Sexagesimal system A numerical system based on the division of 60.

Sheet file A file that brings model files and the border, title block, and other sheet content together to create a drawing for plotting.

Shot Each point surveyed.

Side shots Readings taken from a transit station to specific control points.

Simple curve An arc of a circle with a constant radius (R).

Site analysis plan A plan that provides the basis for the proper design relationship of the proposed development to the site and to adjacent properties.

Site plan A drawing that shows an accurate layout of a piece of land.

Sludge Heavy, suspended material that sinks to the bottom of a septic tank or cesspool.

Slurry pipelines Pipelines used to transport mined ore suspended in water to a processing facility as an alternative to other shipping methods such as railway or trucking.

Soft copy The electronic data file of a drawing or model.

Soil absorption field An underground piping network that distributes the effluent over a large soil area, allowing it to percolate through the soil.

South latitude Parallels south of the prime meridian.

Spatial The location of a feature.

Specific notes Notes that relate to or identify specific, isolated features or instructions within the drawing.

Specification An exact statement describing the characteristics of a particular aspect of a project.

Specifications Separate notes that identify the quality, quantity, type of material used, workmanship, and other detailed information about a project.

Speed hump A mound placed in the road intended to reduce traffic speed and volume.

Spherical excess The amount by which the sum of the angles of a spherical triangle exceeds 180°.

Spherical triangle A three-sided geometric object formed on the surface of a sphere by three great circular arcs intersecting at three vertices.

Spherical trigonometry The study of angles and distances on spherical surfaces.

Spiral curve A curve defined by a constantly changing radius.

Spirit leveling *See* Direct leveling.

Spot elevation An elevation measurement taken at a single location.

Standards A set of technical definitions and guidelines that specify requirements, techniques, and operating procedures.

Standards checking A procedure by which drawings are checked against a base standards drawing that contains up-to-date drawing, design, and construction standards for a specific discipline or trade.

Static terrestrial laser scanning *See* Stationary ground-based laser scanning.

Station point *See* Traverse station.

Stationary ground-based laser scanning A three-dimensional (3-D) laser scanning technology that uses a laser scanner typically set up on a tripod, like a conventional ground survey instrument, and pointed toward the area to be scanned.

Statute mile A unit of measurement exactly equal to 5,280 ft.

Storm sewage Wastewater from rain and groundwater runoff.

Storm sewer A system of underground pipes that carry water runoff from building and land surfaces.

Straight An angle equal to 180° or π radians.

Subdivision A tract of land divided into lots.

Summit curve *See* Crest curve.

Supplementary contour A contour line used when the normal contour interval is too large to clearly illustrate significant topographic features on land with a gentle slope.

Surveying The science of measuring distances, angles, and directions of characteristics of the Earth's surface.

Surveyor A specialist who provides a map file of the job site from which civil designers and drafters develop drawings.

Surveyor's level An instrument with a telescope and spirit level or compensator used to establish a horizontal line for measuring elevations.

Symbol A graphic representation of a feature or an object.

Symbol library A directory of symbols that can be accessed for use on a drawing.

Table An arrangement of rows and columns that organize data to make it easier to read.

Tangent distance (T) The distance along the tangents from the point of intersection (PI) to the point of curve (PC) or point of tangency (PT).

Taping The process of using a tape measure, or tape, to measure distances.

Template (1) A typical road section for a road design taken from a three-dimensional (3-D) path. (2) *See* Drawing template.

Temporary bench mark (TBM) A local control point that is temporary but serves the same purpose as a bench mark.

Text The lettering on a computer-aided design and drafting (CADD) drawing.

Terrain The shape and lay of the land.

Thematic map A map that provides information about specific topics or themes such as the amount of vegetation on the surface of the Earth, observing the effects of wildfires, or plotting human population patterns.

Three-dimensional (3-D) A view displaying width, height, and depth.

Thrust block A block that provides structural support and integrity for pressurized water lines.

Tick mark A small vertical or horizontal line segment on the margin of a map.

Tilt-up concrete A precast concrete construction method using formed wall panels that are lifted, or tilted, into place.

Title block A sheet block that provides a variety of information about a drawing, such as the title, sheet size, and predominant scale.

Topographic map A map that accurately shows the shape of the Earth using contour lines.

Topographic survey A survey that provides accurate location and elevation data of natural and human-made features on land.

Topology A branch of mathematics that deals with relationships among geometric objects.

- Total station** A common piece of conventional surveying equipment used to measure horizontal and vertical distances, and angles.
- Townships** A rectangular grid system of surveys that originate from, and measure north, south, east, and west of the intersection of each baseline and principal meridian; the horizontal rows, or tiers, north and south from the baseline.
- Transit lines** The lines between transit stations.
- Transit station** A survey instrument from which measurements are taken.
- Transition curve** See Spiral curve.
- Traverse** A series of continuous lines connecting points.
- Traverse station** A point connected by a traverse.
- Triangulated irregular network (TIN)** A surface model formed by triangulating a set of points.
- Triangulation stations** The vertices of the triangulation triangles.
- Triangulation** The method of establishing a triangle or series of adjoining triangles as a network in order to determine the distances and locations of points based on measured interior angles and two known points.
- Trilateration** The method of establishing a triangle or series of triangles in order to determine the locations of points based on measured distances and two known points.
- True azimuth (TA)** A horizontal angle measured using true north as the reference line.
- True meridian** See True north.
- True north (TN)** The location of the north pole.
- Turning point (TP)** A temporary bench mark such as a large rock, fire hydrant (FH), concrete curb or foundation, wooden stake, or metal spike, on which the rod is rested and used as a pivot for the rod.
- Two-dimensional (2-D)** A view displaying only width and height, width and length, or height and length.
- Typical cross section** A cross section common to any location along a feature, such as a street.
- Typical detail** A detail drawing common to any location associated with the feature, standard, or code addressed by the detail.
- United States survey foot** A unit of measurement 1,200/3,937 m, or 0.3048006096 m.
- Uniform slope theory** A theory based on equal spacing of contours between known points.
- Universal Transverse Mercator (UTM)** A coordinate system based on the Transverse Mercator map projection that divides most of the world into 60, 6° longitude-wide zones between 84° north latitude and 80° south latitude.
- Unmanned aerial system (UAS)** See Unmanned aerial vehicle.
- Unmanned aerial vehicle (UAV)** An aircraft operated by remote control or computer without an onboard human pilot.
- Utility easement** An easement used for utilities; generally a portion of land, shared by a property owner and a public agency, that contains a public utility, such as electrical power, telephone, and/or sewer lines.
- Vectorization** The conversion of raster data to vector.
- Vegetation symbols** Symbols that represent forests, orchards, croplands, and other types of plant life.
- Verbal scale** A close approximation of scale for discussion purposes only.
- Vertex** The intersection of arms or sides of an angle.

- Vertical alignment** A definition of the vertical form, or change in elevation, of a route on a vertical plane, or profile.
- Vertical curve** A feature that is provided to change vertical alignment between different slopes.
- Vertical datum** The zero elevation reference for elevations of surfaces and features on the Earth.
- Verticals** Industry-specific versions of software.
- Vicinity map** A map that places a project site within a large area, such as several square miles, and provides an overview of the site relative to the surrounding area.
- Viewshed determination** Identifying all locations that can be seen from a specific site.
- Virtual** Something that appears to have the properties of a real or actual object or experience.
- Voxel feature** A three-dimensional (3-D) polygon used to model flow of air and water.
-
- Water symbols** Symbols that represent water features such as lakes, rivers, streams, and intermittent waters.
- Wblock** An AutoCAD block definition saved as a separate drawing file.
- Web GIS** A system that uses web technologies to communicate between a geographic information system (GIS) server and a client web browser, desktop application, or mobile application.
- Wildfire zones** Heavily wooded areas and can be confirmed at the local building official or zoning office.
- Wood-frame construction** Construction that uses dimensional lumber nailed together to form a supporting framework covered with a variety of surfacing materials.
-
- Zoning** A system of land use planning and public restrictions applied by local governments.
- Zoning map** A map typically used to layout and categorize districts within a town, city, or state.
- Zoom** A command that allows you to zoom in to make objects appear larger and zoom out to make objects appear smaller without affecting the actual size of the objects.

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Abbreviations

#	Pound; Number	ANCH	Anchor; Anchorage
&	And	ANSI	American National Standards Institute
Δ	Delta angle	AP	Access Panel
@	At	APPD or APRVD	Approved
"	Double prime; Inch	APPROX or APX	Approximately; Approximate
'	Prime; Foot	ARCH	Architect; Architectural
°	Degree	AREMA	American Railway Engineering and Maintenance-of-Way Association
Ø	Diameter	ASCE	American Society of Civil Engineers
2-D	Two-dimensional	ASEE	American Society for Engineering Education
3-D	Three-dimensional	ASME	American Society of Mechanical Engineers
AASHTO	American Association of State Highway and Transportation	ASPH	Asphalt
AB	Anchor bolt	ASSEM	Assemble
ABDN	Abandon	ASSOC	Association; Associate
ABV	Above	ASSY	Assembly
AC	Asbestos cement; Asphaltic concrete	ASTM	American Society for Testing and Material
ACC	Access	AUTO	Automatic
ACEC	American Council of Engineering Companies	AVG	Average
ACL	Across the line	AWS	American Welding Society
AD	Access door; Area drain	AWWA	American Water Works Association
ADA	Americans with Disabilities Act of 1992	AX	Axis
ADD	Addendum; Addition	B & B	Balled and burlapped
ADDA	American Design Drafting/ American Digital Design Association	B TO B	Back to Back
ADDL	Additional	B/	Bottom of
ADH	Adhesive	B/U	Built up
ADJ	Adjacent; Adjustable	BBL	Barrel
AEC	Architecture, engineering, and construction	BDY	Boundary
AF	Above floor	BEL	Below
AFF	Above finished floor	BET or BETW	Between
AGG	Aggregate	BEV	Bevel
AHR	Anchor	BF	Board foot; Back face; Bottom face; Both faces
AIA	American Institute of Architects	BG	Bag
AISC	American Institute of Steel Construction	BGS	Below ground surface
ALS	Airborne laser scanning	BIM	Building information modeling
ALT	Alternate; Alteration; Altitude	BKGD	Background

BL	Base line; Building line; Block	CI	Cast iron
BLDG	Building	CIN BL	Cinder block
BLK	Block	CIP	Cast-in-place; Cast iron pipe
BLKG	Blocking	CIR	Circle; circular
BLT	Bolt	CIRC	Circumference
BLT-IN	Built-In	CISP	Cast iron soil/sewer pipe
BLW	Below	CJ	Construction joint; Control joint
BM	Beam; Bench mark	CL	Centerline; Clearance; Closing; Closure; Class
BNT	Bent	CLG	Ceiling
BOE	Bottom of excavation elevation	CLR OPG	Clear opening
BOF	Bottom of footing/foundation elevation	CLR	Clear; Clearance
BOGB	Bottom of grade beam elevation	CLS	Closure
BOM	Bill of materials	CM	Circular Mil (1/1,000 inch)
BOS	Bottom of slab elevation	CMP	Corrugated metal pipe
BOT	Bottom	CMU	Concrete masonry unit
BP	Base plate; Blueprint; Bypass	CNTR	Center; Counter
BPL	Bearing plate	CNVR	Conveyor
BR	Brick; Brass	CO & DP	Cleanout and deck plate
BRDG	Bridge; Bridging	CO	Cleanout; Company; Cased opening; Cut-out
BRG	Bearing	COD	Cleanout Door
BRK	Brick	COGO	Coordinate geometry
BRKT	Bracket	COL	Column
BS	Both sides; Backset; Bluestone	COM	Common
BSMT	Basement	COMP	Composition; Compressed
BT	Bolt	CONC	Concrete; Portland cement concrete
BTR	Better	CONN	Connection
BVC	Begin vertical curve	CONST or CONSTR	Construction
BVL	Beveled	CONT	Continue; Continuous; Control
BW	Both ways	CONTR	Contractor
BYP	Bypass	CORR	Corridor; Corrugate
C TO C	Center to center	COV	Cover
C	Course; Curb; Channel; Degrees Celsius	CP	Cesspool
C/C	Center to center	CPR	Copper
CAB	Cabinet	CRS	Cold rolled steel; Course
CAD	Computer-aided drafting; Computer-aided design	CS	Countersink; Cast steel; Cast stone; Commercial standard
CADD	Computer-aided design and drafting	CSG	Casing
CAP	Capacity	CSI	Construction Specifications Institute
CAT	Catalog	CSK	Countersink
CAV	Cavity	CSMT	Casement
CB	Catch basin; Concrete block	CSO	Combined sewerage outlet
CBL	Concrete block	CSP	Concrete sewer pipe
CC	Cubic centimeter	CSTG	Casting
CCP	Concrete cylinder pipe	CT	Count
CCW	Counterclockwise	CTD	Cumulative trauma disorder
CEC	Certified consulting engineer	CTR	Center; Counter
CEM	Cement	CU. FT.	Cubic feet
CF	Cubic feet	CU. YD.	Cubic yard
CFM	Cubic feet per minute	CV	Check valve
CFS	Cubic feet per second	CW	Clockwise; Cold water
CHAM	Chamfer	CY	Cubic yard; Cycle
CHAN	Channel		

CYL	Cylinder	EOP	Edge of pavement
D	Deep; Depth; Diameter; Drain; Drop	EQ	Equal
D	Degree of curve	EQL SP	Equally spaced
DB	Database	EQP or EQPT	Equipment
DBL	Double	EST	Estimate
DBMS	Database management system	EVC	End vertical curve
DD	Driveway drain; Deck drain	EW	Each way
DEG	Degree	EX	Exposed construction; Exit
DEGC	Degree Celsius	EXC or EXCAV	Excavate
DEGF	Degree Fahrenheit	EXIST or EXST	Existing
DEM	Demolish	EXT	Exterior; extension
DEM	Digital elevation model	F TO F	Face to face
DEMO	Demolition	F	Degrees Fahrenheit
DEP	Depressed	FAB or FABR	Fabricate
DEPT	Department	FAST	Fastener; Fasten
DEQ	Department of Environmental Quality	FCO	Floor cleanout
DET	Detail	FD	Floor drain
DF	Drinking fountain	FDN or FDTN	Foundation
DIA	Diameter	FE	Fundamentals of Engineering
DIAG	Diagonal	FF or FFE	Finished floor elevation
DIAM	Diameter	FFL	Finished floor line
DIM	Dimension	FG	Finish grade elevation; Finish grade
DIR	Direction	FH or FHY	Fire hydrant
DIST	Distance	FHWA	Federal Highway Administration
DIV	Division	FIN	Finish; Finished
DMH	Drop manhole	FIX or FIXT	Fixture
DN	Down	FL	Floor; floor line; flow
DO	Ditto; Door opening	FLL	Flow line
DOD	U.S. Department of Defense	FLR	Floor
DR	Door; Drain	FO	Finished opening
DR	Drain	FOC	Face of concrete
DS	Downspout; Disconnect switch; Door switch	FOF	Face of finish
DSM	Digital surface model	FPM	Feet per minute
DSP	Dry standpipe	FPS	Feet per second
DT	Drain tile	FS	Foresight; Full size; Far side
DTL	Detail	FT	Foot; Feet
DTM	Digital terrain model	FTG	Footing; Fitting
DWG	Drawing	FUT	Future
DWGS	Drawings	G	Gas; Girder; Gutter; Gram
E TO E	End to end	GA	Gauge; Gage
E	East; Exhaust	GAGE	Gauge
E	External distance	GAL	Gallon
EA	Each	GALV	Galvanized
EDM	Electronic distance meter	GB	Grade beam; Grab bar; Glass block; Gypsum board
EE	Each end	GC	General contractor
EF	Each face	GD	Guard; Grade; Gutter drain
EG	Existing grade	GEN	General; Generator
EL	Elevation	GENL	General
ELEV	Elevation; Elevator	GF	Ground face
EMA	East magnetic azimuth	GFRC	Glass fiber reinforced concrete
EMD	East magnetic declination	GI	Galvanized iron
ENG or ENGR	Engineer	GIS	Geographic information system
ENT	Entrance		

GKT	Gasket	K	Kilopound (1000 pounds);
GL	Glass		Kelvin (temperature)
GM	Silty gravel	KG	Kilogram
GN	Grid north	KM	Kilometer
GND or GRND	Ground	I	Intersecting angle
GNSS	Global navigation satellite system	L	Length of curve; Angle; Left; Length; Long; Line
GOVT	Government	LAT or LATL	Lateral
GP	Galvanized pipe; Poorly graded gravel	LB	Pound
		LBL	Label
GPH	Gallons per hour	LC	Long chord
GPM	Gallons per minute	LF	Lineal feet
GPS	Gallons per second; Global positioning system	LH	Left hand
		LIB	Library
GR or GRD	Grade	LID	Low impact development
GR	Grid north; Material grade	LIDA	Low impact development approach
GRS 80	Geodetic Reference System 1980	LiDAR	Light Detection and Ranging
GTV	Gate valve	LIN	Linear
GVL	Gravel	LLA	Latitude, longitude, and altitude
GW	Well-graded gravel		
H	High	LN	Length
HD	Head; Heavy duty	LNDG	Landing
HGT	Height	LOC	Locate
HI	Height of the instrument	LOCS	Locations
HL	Hydrant line	LONG	Longitudinal
HOR or HORIZ	Horizontal	LP	Low point
HR	Hour	LT WT or LW	Lightweight
HSG	Housing	LT	Light
HVY	Heavy	LWC	Lightweight concrete
HWY	Highway	M	Meter
HYD	Hydraulic	M	Middle ordinate
ID	Inside diameter	MAINT	Maintenance
IE	Invert elevation	MAN	Manual
IF	Inside face	MAS	Masonry
IFS	Intermediate foresight	MAT or MATL	Material
IMH	Inlet manhole	MAX	Maximum
IMU	Internal measurement unit	MD	Magnetic declination
IMW	International Map of the World	MECH	Mechanical
IN	Inch	MED	Medium
INCL	Incline; Include	MET	Metal
INCR	Increase	MFD	Manufactured
INFL	Influent	MFG or MFR	Manufacture; Manufacturer; Manufacturing
INFO	Information		
INSP	Inspect	MH	Manhole
INSTL	Install; Installation	MI	Miles
INT or INTR	Interior; Internal	MIL	Thousandth of an inch (0.001 in)
INTERM or INTM	Intermediate		
INV	Invert	MIN	Minimum
IP	Iron pipe	MISC	Miscellaneous
IPS	Iron pipe size	MK	Mark
ISO	International Organization for Standardization	MLS	Mobile laser scanning
		MM	Millimeter
IW	Indirect waste	MN	Magnetic north
JCT	Junction	MO	Masonry opening
JT	Joint	MOD	Module

MON	Monument	PCC	Portland cement concrete
MONO	Monolithic	PCF	Pounds per cubic foot
MOV	Movable	PDF	Portable document format
MSL	Mean sea level	PE	Professional engineer
MT or MTD	Mount; Mounted	PERIM	Perimeter
MTL	Material; Metal	PERP	Perpendicular
MTO	Material take off	PI	Point of intersection
NA	Not applicable	PKG	Parking
NACFAM	National Council for Advanced Manufacturing	PKWY	Parkway
NAD 83	North American Datum 1983	PL	Plate; Plan; Property line
NAT or NATL	Natural	PLBG or PLUMB	Plumbing
NAVD 88	North American Vertical Datum of 1988	PLF	Pounds per lineal foot
NAVSTAR	Navigation Signal Timing and Ranging	PLG or PLMBG	Plumbing
NCS	United States National CAD Standard	PLG	Piling
NF	Near face	PLM	Product lifecycle management
NGS	National Geodetic Survey	PLS	Professional land surveyor
NIBS	National Institute of Building Sciences	PLSS	Public Land Survey System
NIC	Not in contract	PLTF	Platform
NIL	Negligible	POB	Point of beginning
NOAA	National Oceanic and Atmospheric Administration	POT W	Potable water
NOM	Nominal	PP	Piping
NS	Near side	PR	Pair
NSRS	National Spatial Reference System	PRC or PRCST	Precast
NTS	Not to scale	PRC	Point of reverse curve
O TO O	Out to out	PRES or PRESS	Pressure
OA	Outside air; Overall	PRI	Primary
OC	On-center	PRV	Pressure reducing valve
OD	Outside diameter	PSF	Pounds per square foot
OF	Outside face	PSI	Pounds per square inch
OH	Overhead	PT	Point of tangency
OHD	Overhead door	PUD	Planned unit development
OMB	U.S. Office of Management and Budget	PUE	Public utility easement
OOS	Occupational overuse syndrome	PV or PVG	Paving
OPG or OPNG	Opening	PVC	Polyvinyl chloride
OPP	Opposite	PVMT	Pavement
OR	Outside radius	PVT	Private
ORIG	Original	PWR	Power
OSD	Open sight drain	QTO	Quantity take off
OSHA	Occupational Safety and Health Administration	QTR	Quarter
OVFL	Overflow	QTY or QUANT	Quantity
OZ	Ounce	QUAL	Quality
P SL	Pipe sleeve	R or RAD	Radius; Radius curve
P	Pitch	RADN	Radian
PAR	Parallel	RC	Reinforced concrete
PASS	Passage	RCP	Reinforced concrete pipe
PC	Point of curve; Precast concrete	RD	Rain drain; roof drain
		RDBMS	Relational database management systems
		REBAR	Reinforcing bar
		REM	Remove; Removable
		REPL	Replace
		REQ or REQD	Require; Required
		RET	Return; Retaining
		RETG	Retaining
		REV	Reverse; Revise; Revision
		RF	Representative fraction

RF	Roof	SYN	Synthetic
RGH OPNG	Rough opening	SYS	System
RGH	Rough	T & B	Top and bottom
RH	Right hand	T & G	Tongue and groove
RMI	Repetitive movement injury	T or TD	Tangent distance
RMV	Remove	T	English ton (2,000 pounds)
ROW	Right of way	T/	Top
RPM	Revolutions per minute	T/B	Top and bottom
RPT	Repeat	TA	True azimuth
RR	Railroad	TAN	Tangent
RSI	Repetitive strain injury	TBM	Temporary bench mark
RT	Right	TC	Top of concrete; Top of curb
RW	Right-of-way	TD	Tangent distance
S	Percent slope; South; Supply	TEMP	Temporary; Temperature
SA	Selective availability	TF	Top face
SAN	Sanitary	THK	Thick; Thickness
SCH or SCHED	Schedule	THKNS	Thickness
SD	Storm drain	THRU	Through
SE	Structural engineer	TIN	Triangulated irregular network
SEC	Second; Section; Secondary	TN	True north
SECT	Section	TO	Top of
SF	Square feet	TOC	Top of curb
SH or SHT	Sheet	TOF	Top of foundation elevation
SI	International System of Units	TOGB	Top of grade beam elevation
SIG	Signal	TOL	Tolerance
SIM	Similar	TOS	Top of slab elevation
SPCS 27	State Plane Coordinate System of 1927	TP	Top of pavement
SPCS 83	State Plane Coordinate System of 1983	TP	Turning point
SPCS or SPS	State Plane Coordinate System	TSF	Tons per square foot
SPEC	Specification	TSL	Top of slab; Top of steel
SPECS	Specifications	TW	Top of wall
SPL	Special	TYP	Typical
SQ	Square	UAS	Unmanned aerial system
SS	Sanitary sewer	UAV	Unmanned aerial vehicle
SSMH	Sanitary sewer manhole	UC	Undercut
ST W	Storm water	UDS	Uniform Drawing System
ST	Straight; Storm water	UNEX	Unexcavated
STA	Station	UNO	Unless noted otherwise
STD	Standard	USFS	U.S. Forest Service
STGR	Stagger	USGS	U.S. Geological Survey
STL	Steel	USS	United States Standard
STR	Straight; Strainer; Structural; Starter	UT	Utility
STRL	Structural	UTM	Universal Transverse Mercator
STRT	Straight	V	Vertex
STRUC	Structural	VAR	Variable
STRUCT	Structure	VC	Vertical curve
SUPP	Supplementary; Supplement	VERT	Vertical
SUR	Surface	VIF	Verify in the field
SUSP	Suspended; Suspend	VLT	Vault
SW	Percent soil swell when wet; Southwest	VOL	Volume
SY	Square yard	W	West; Width; Wide; Waste; Water; Water main
SYM or SYMM	Symmetrical	W/	With
		W/O	Without
		WD	Wood
		WF	Wide flange

WGS 84	World Geodetic System of 1984	WT	Weight; Water table
WI	Wrought iron	X HVY	Extra heavy
WM	Wire mesh; Water meter	X STR	Extra strong
WMA	West magnetic azimuth	XH	Extra heavy
WMD	West magnetic declination	YD	Yard
WS	Water surface; Welded steel	YR	Year

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Index

A

Acute angle, 206
 ADDA (American Design Drafting Association), 5–6
 AEC (Architecture, engineering, and construction), 34
 Aerial laser scanning (ALS), 153–154
 Aerial photographs, 134, 137. *See also* Photogrammetry
 Aerotriangulation, 150
 AIA (American Institute of Architects), 34
 AIA CAD Layer Guidelines, 58
 Airborne laser scanning, 153–155
 Alignments, CADD
 creating, 317–318
 defined, 310
 editing, 318–320
 extended, 321
 horizontal, 310
 with horizontal layout, 317–321
 labeling, 320
 vertical, 310
 All-weather driveway surface, 286
 American Association of State Highway and Transportation Officials (AASHTO), 312
 American Council of Engineering Companies (ACEC), 6
 American Design Drafting Association/American Digital Design Association (ADDA)
 employment center, 6
 instructor and curriculum certification programs, 6
 professional certification programs, 5–6
 American Institute of Architects (AIA), 34
 American National Standards Institute (ANSI), 34
 American Society for Engineering Education (ASEE), 7
 American Society of Civil Engineers (ASCE), 7
 American Society of Mechanical Engineers (ASME), 34
 Angle of repose, 372–374
 Angles, 204–206
 acute, 206
 central, 314
 decimal degrees, 205
 defined, 204
 deflection, 212
 degrees decimal minutes, 205
 degrees minutes seconds, 204
 delta (Δ), 282, 314
 full, 205
 included, 206, 282, 314
 intersecting (I), 205–206, 314
 obtuse, 206

 reflex, 205
 of repose, 372–374
 right, 205, 206
 Angular measurement, 168
 ANSI (American National Standards Institute), 34
 Antarctic topographic maps, 87
 ArcGIS, 453
 ARCHICAD software, 47
 Architecture, engineering, and construction (AEC), 34
 Arcs, 168
 Area feature, in GIS, 457
 As-built drawings, 32, 138
 As-built surveys, 137–138
 ASCE (American Society of Civil Engineers), 7
 ASEE (American Society for Engineering Education), 7
 ASME (American Society of Mechanical Engineers), 34
 Attribute data
 defined, 52, 116
 GIS, 457–459
 AutoCAD
 assembly, 388
 breakline, 389
 corridor, 389
 daylighting, 389
 daylight line, 389
 feature lines, 389
 grading object, 392, 393
 model space system, 70, 71, 97, 98
 paper space or layout, 70, 71, 97, 98
 roadway cut-and-fill layout, 376–377
 software described, 47
 symbols, 116
 template, 388–390
 3-D chain, 388
 3-D view, 389, 390
 AutoCAD Civil 3D software, 47
 Autodesk, Inc., 47, 452
 Automated mapping and facilities management (AM/FM), 469
 Average end method, 385–386
 Azimuth, 208–210
 defined, 208
 grid, 210
 magnetic, 209
 true, 209

B

Backsight (BS), 182
 Back tangent, 313
 Barricades, 410, 413
 Baseline, 247, 274
 Base stations, 149
 Bearings

 defined, 210
 magnetic, 211
 true, 211
 Bench mark (BM), 132, 180–181, 213
 Bentley Systems, Inc., 47, 453
 Blocks
 defined, 116
 thrust, 417
 title, 8
 Border, 8
 Borrow pits, 386–388
 Boundary surveys, 134
 Breaking chain, 179
 Breakline, 144, 383
 Buffering, 462
 Building information modeling (BIM), 46, 49–53
 standards, 53

C

CAD. *See* Computer-aided design and drafting (CADD)
 Cadastral maps, 15
 Cadastral surveys, 134
 CADD. *See* Computer-aided design and drafting (CADD)
 CAD Layer Guidelines, 34
 Caliper Corporation, 453
 Carlson Grade software, 47
 Carlson Software, 47
 Carpal tunnel syndrome, 76
 Cartesian coordinate system, 160–162
 Cartographers, 8
 Cartography, 8, 471
 Catch basins, 411, 416, 423
 Central angle, 314
 Cesspools, 282
 Chaining, 178
 Charts
 aeronautical, 20
 defined, 7
 nautical, 19
 Checking drawing standards, 36
 Chord, 133, 282
 Circular curve, 312
 Civil drafting
 as-built drawings, 32
 civil engineering, 2–5
 cross section, 27–30
 defined, 2, 54
 design and drafting process, 23–32
 detail drawings, 30–31
 drafting standards, 32–36
 education and qualifications, 4–5
 employment opportunities, 3–4
 plan drawings, 27
 professional organizations, 5–7
 profile drawings, 27–30

- Civil engineering
 - defined, 2
 - and GIS, 465–468, 471
- Client
 - defined, 35
 - standards, 35
- Closed traverses, 212, 215–217
- Closure, error of, 219–221
- Code
 - defined, 32
 - of ethics, 36
- Collar, 175
- Combined sewerage outlet (CSO), 411
- Company standards, 35
- Compound curve, 313
- Computer-aided design (CAD). *See* Computer-aided design and drafting (CADD)
- Computer-aided design and drafting (CADD)
 - creating alignments, 317–318
 - defined, 4
 - dimensions, 62–63
 - editing alignments, 318–320
 - ergonomics, 76–78
 - extended alignment, 321
 - file management guidelines, 74
 - file organization, 73–74
 - formats, 48–49
 - and GIS, 457, 472–473
 - horizontal alignment layout with, 317–321
 - labeling alignments, 320
 - layers, 56–58, 455–456
 - notes and specifications, 60–62
 - plotting, 70–73
 - productivity with, 75–76
 - reusing drawing content, 75–76
 - scales, 96–99
 - sheet size and format, 65–70
 - site plan cut-and-fill layout, 378–380
 - site volume calculations, 393
 - symbols, 64–65
 - tables, 63–64
 - template drawings, 76
 - text, 58–60
 - U.S. National CAD Standard, 54
- Computer-aided drafting (CAD). *See* Computer-aided design and drafting (CADD)
- Computer-aided Drafting and Design (CADD) Skill Standards*, 35
- Computer science, GIS, 471
- Concrete block. *See* Concrete masonry unit (CMU)
- Concrete masonry unit (CMU), 421–422, 436
- Connecting traverse, 212
- Construction Specifications Canada (CSC), 62
- Construction Specifications Institute (CSI), 34, 62
- Construction surveys, 137, 140
- Consulting engineering, 3
- Contour interval, 228
- Contour lines, 228–251
 - with civil CADD, 247–251
 - control point surveys, 238
 - defined, 12, 108, 111, 228
 - grid surveys, 242–243
 - interpolating by estimation, 238–240
 - interpolating, mathematical, 240–242
 - plotting, 238–247
 - radial surveys, 247
 - relief features, 232–235
 - ridges and valleys, 231–232
 - slopes, 229–231
 - types, 235–238
 - values, 237
- Control point surveys, 238
- Control segment, 147–148
- Control surveys, 133–134
- Conversions
 - graphic scale to representative fraction, 91–92
 - inch-to-metric, 93, 95
 - metric-to-U.S., 93, 95
 - representative fraction to graphic scale, 90–91
 - U.S.-to-metric, 93, 95
- Coordinate geometry (COGO), 215
- Coordinates
 - latitude, longitude, and altitude (LLA), 148
 - system, 160
- Corner cube prism, 177
- Corners, 277
- Credit legend, 175
- Cross sections
 - CADD, 390–391
 - defined, 381
 - field notes, 384
 - level, 384–385
 - street, 391
 - surveys, 381, 383–384
 - view, 27, 381
- CSI (Construction Specifications Institute), 34
- Cul-de-sacs, 409, 410
- Culture symbols, 108–111
- Cumulative trauma disorder (CTD), 76
- Curvature, point of, 314
- Curve length, 314
- Curves
 - circular, 312
 - compound, 313
 - degree of, 315
 - horizontal, 312
 - left-hand, 314
 - point of, 314
 - point of reverse, 315
 - right-hand, 314
 - simple, 312
 - spiral, 313
 - transition, 313
- Cut and fill
 - average end method, 385–386
 - building site plan, 378–380
 - crawler dozer, 372, 373
 - defined, 372
 - roadways, 372–378
- Cutting-plane line, 28

- D**
- Data
 - analysis, 460–462
 - attribute, 457–459
 - display, 462–463
 - formats, 459–463
 - spatial, 456–458
- Database (DB), 458
- Database management system (DBMS), 458
- Datum, 160
- Deflection angle, 212
- Degree, 162, 204
- Degree of curve (D), 315
- Delta angle (Δ), 282, 314
- Delta notes, 61
- DEM (digital elevation model) maps, 20
- Demographic analysis, 466–467, 469
- Denominators, 86–87
- Department of Environmental Quality (DEQ), 279
- Departures, 217–219
- Desktop GIS, 452
- Detail drawings. *See also* Drawings
 - defined, 30, 406–440
 - format, 406–408
 - handrail, 423, 440
 - pictorial view, 411, 414
 - piping, 419, 431–433
 - road, 409–413
 - rock retaining wall, 423, 439
 - sewers sanitary, 416, 422, 423
 - steel, 422, 438
 - storm sewers, 411, 415–418
 - stream step pools, 423, 440
 - structural, 419–422, 434–438
 - tree protection, 423, 439
 - water, 416–418, 427–430
 - wood, 422, 437
- Detail reference symbol, 407
- Differential correction, 149
- Differential GPS, 149
- Differential leveling, 181
- Digital elevation model (DEM) maps, 20
- Digital surface model (DSM), 20
- Digital terrain model (DTM)
 - CADD, 310
 - contour lines, 238
 - defined, 21
 - survey data, 143
- Dimensions, 62–63
- Direction, 206–211
 - azimuth, 208–210
 - bearing, 210–211
 - defined, 204
 - grid azimuth, 210
 - grid north (GN), 206
 - local attraction, 209
 - magnetic declination, 207–208
 - magnetic north (MN), 206
 - true azimuth (TA), 209
 - true north (TN), 206
- Direct leveling, 181
- Dividers, mechanical, 89
- Domestic sewage, 279, 411
- Drafting standards
 - checking drawing standards, 36
 - client standards, 35
 - company standards, 35
 - government standards, 35
 - professional organization standards, 34–35
 - project standards, 35–36
- Drainage, 388
- Drainfield, 282
- Drawing content, reusing, 75–76
- Drawing property lines, 287–288
- Drawings
 - as-built, 32
 - detail, 30–31
 - exporting, 72
 - limits, 98
 - manual, 5
 - plan, 27
 - profile, 27–30
 - property lines, 287–288
 - scale, 70
 - template, 76
- Drone. *See* Unmanned aerial vehicles (UAVs)
- DSM (digital surface model), 20
- DTM. *See* Digital terrain model (DTM)

E

Earthwork, 371–393
 borrow pits, 386–388
 calculations, 384–388
 with civil CADD, 388–393
 cross sections, 381–384
 cut and fill, average end method, 385–386
 cut and fill layout, building site plan, 378–380
 cut and fill layout, roadway, 372–378
 defined, 372
 drainage considerations, 388
Easement, 279
East longitude, 163
East magnetic declination (EMD), 207–208
Effluent, 282
Electronic distance meter (EDM), 139, 177
Electronic plotting method, 72
Elevations
 defined, 7, 111, 179, 228
 spot, 144
Engineering maps, 16–17
Engineer's scale, 92, 93
Ergonomics, 76–78
Erosion control, 415, 421
Error of closure, 219–221
Esri, Inc., 453
Ethics, 36
Exercises, 78
Exporting, drawing, 72
External distance (E), 315
Extracting, 462

F

Facilities management, 469, 471
Federal Highway Administration (FHWA), 312
Field notes
 cross sections, 384
 surveying, 142–145
Fields, 61
Firebreak, 287
Fire hydrant (FH), 183, 418, 428, 429
Floating viewports, 96–97
Fonts, 58
Footings, 422
Footplate, 181
Foresight (FS), 182, 383
Formulas, offset distance, 379
Forward tangent, 314
Full angle, 205
Full station, 310, 383
Fundamentals of Engineering (FE), 5

G

General discipline notes, 62
Generalizing, 462
General notes, 60–61
General sheet notes, 62
Geocentric datum, 161
Geocoding, 467, 470
Geodesy, 130, 471
Geodetic datum, 160
Geodetic Reference System 1980 (GRS 80), 162
Geodetic surveys, 130–132
Geographic coordinate system, 162–169
 latitude, 163
 longitude, 163–164
 maps, locations on, 164–169
Geographic information system (GIS)

 applications, 463–470
 attribute data, 457–459
 and CADD, 457, 472–473
 civil engineering based applications, 465–468
 concepts, 453–463
 data analysis, 460–462
 data display, 462–463
 data formats, 459–463
 defined, 4, 452
 demographic analysis, 466–467, 469
 facilities management, 469, 471
 in forestry industry, 454, 455
 geocoding, 467, 470
 and GPS, 149, 150
 hypermedia, 459
 land use planning, 463
 layers, 455–456
 modeling, 469–470, 472
 natural resources management, 464
 open source application, 452
 receivers and features, 149, 150
 related disciplines, 470–473
 software products, 452–453
 spatial data, 456–458
 3D analysis, 469–470, 472
 topology, 460
 utilities management, 469
Geographic meridian, 206
Geographic north, 206
Geography, 471
Geologic maps, 13–14
Geomatics, 3
Georeferenced image, 152
Georelational data model, 454
Girder, 52–53
Global Navigation Satellite System (GNSS), 146–150, 177, 207
Global positioning system (GPS)
 aerotriangulation, 150
 base stations, 149
 errors, differential correction, and accuracy, 149, 150
 position determination, 147–148
 satellites, 146–147
 uses, 146
Government standards, 35
GPS. *See* Global positioning system (GPS)
Grade, 378
Grading
 defined, 267
 plans, 267
Graphic patterns, 115, 118, 119
Graphic scale, 87–92
 converting from representative fraction, 90–91
 converting to representative fraction, 91–92
 defined, 87
Graphic symbols legend, 113, 117
Graphisoft, 47
Great circular arcs, 168
Grid azimuth, 210
Grid north (GN), 175, 206
Grids, in raster data format, 459
Grid surveys, 242–243
 interpolating contours, 243–247

H

Hard copies, 70
Height of the instrument (HI), 182
High-resolution surveying. *See* Stationary ground-based laser scanning
Horizontal alignment layout
 with CADD, 317–321

 centerline (route) survey, 310–312
 curve layout, 312–317
 defined, 310
 plan layout, 310–312
Horizontal curve
 components of a simple curve, 313–315
 curve layout, 315–317
 defined, 312
Horizontal distances, 175–179
 EDM, 177
 measuring distances methods, 177–179
Hydraulic surveys, 134
Hydrographic maps, 15
Hydrographic surveys, 134, 136
Hydrologic study, 388
Hypermedia, 459
Hypotenuse, 167

I

Inch-to-metric conversions, 93, 95
Inclined road layout, 377–379
Inclined text, 59
Included angle, 206, 282, 314
Index contour, 235
Inertial measurement units (IMUs), 153–154
Insertion base point, 116, 117
Intellectual property rights, 36
Intergraph Corporation, 453
Intermediate contours, 236–237
Intermediate foresight (IFS), 182, 383
International Map of the World (IMW), 87
International Organization for Standardization (ISO), 34
Interpolating contour lines
 by estimation, 238–240
 for grid surveys, 243–247
 mathematical, 240–242
Interpolation, 150
Intersecting angle (I), 314
Intersection, point of, 314
ISO (International Organization for Standardization), 34

K

Key notes, 61
Keys, 10, 113, 458

L

Land surveys, 134, 135
Land use planning, GIS, 463, 464
Laser detector, 186
Laser receiver, 186
Laser scanning, 150–156
 3-D, 150–156
Latitude, longitude, and altitude (LLA)
 coordinates, 148
Latitudes, 217–219
 defined, 163
 lines of, 162
 negative, 218
 North, 163
 parallels of, 162
 positive, 217
 South, 163
Layers
 CADD, 56–58, 455–456
 GIS, 455–456
Layout, 70, 96
Leach lines, 282
Left-hand curve, 314

Legal descriptions, complete, 277–279
 Legends
 defined, 113, 117
 map, 10
 Length of curve (L), 314
 Level cross sections, 384–385
 Leveling
 defined, 181
 differential, 181
 direct, 181
 field data, 185
 precision, 185
 process, 181–183
 spirit, 181
 Level pole, 181
 Level rod, 181
 Level staff, 181
 Library files, 73
 Light detection and ranging (LiDAR), 151
 Light-frame construction, 422, 437
 Limits, drawing, 98
 Line colors, 55–56
 Line conventions, 55
 Line feature, in GIS, 457
 Line laser level, 186
 Lines. *See also* Contour lines
 contour, 12
 drawing property, 287–288
 feature, 457
 laser level, 186
 of latitude, 162
 leach lines, 282
 of longitude, 162
 thickness, 55
 transit, 247
 weights, 55, 56
 work, 55–56
 Line thickness, 55
 Line weights, 55, 56
 Line work, 55–56
 LLA (latitude, longitude, and altitude)
 coordinates, 148
 Local attraction, 209
 Local control points, 182
 Local notes, 61
 Location, 158
 Long chord (LC), 315
 Longitude, 163–164. *See also* Meridians
 East, 163
 of lines, 162
 West, 164
 Lot and block, 272
 Lots, 262
 Low impact development (LID), 414
 Low impact development approach
 (LIDA), 414

M

Machine control process, 47
 Magnetic azimuth, 209
 Magnetic bearings, 211
 Magnetic compass, 206
 Magnetic declination (MD), 207–208
 Magnetic meridian, 206
 Magnetic north (MN), 175, 206
 Magnetic variation (MV), 207
 Maintenance hole, 281. *See also* Manhole
 Major contour, 235
 Manhole
 cover, 281
 defined, 281, 411, 417, 418
 Manifold Software Limited, 453
 Manual drawings, 5
 Map coordinate systems

 defined, 169
 SPCS, 172–174
 UTM, 169–172
 Map legends, 10
 Map projections
 defined, 169
 SPCS, 172–174
 UTM, 169–172
 Maps
 Antarctic topographic, 87
 cadastral, 15
 defined, 7, 86
 digital elevation model, 20
 elements, 8–10
 engineering, 16–17
 fundamentals, 7–10
 geologic, 13–14
 hydrographic, 15
 international map of the world, 87
 military, 14
 1:250,000 scale, 87
 photogrammetric, 11
 physical, 10
 planning, 18–19
 political, 10
 quadrangle, 12–13, 175, 229
 shaded relief, 87
 small-scale, 87
 special, 87
 state, 87
 thematic, 10–11
 topographic, 12, 229
 of types, 10–22
 vicinity, 27, 262
 zoning, 19
 Map scales, 86–89. *See also* Scales
 Map symbols, 107–121
 types of, 108–113
 Margin, 175
 MasterFormat
 defined, 62
 library file naming system, 73
 Material take off (MTO), 53
 Mathematical interpolation of contour
 lines, 240–242
 Mathematics, 471
 Mean sea level (MSL), 180
 Measuring wheel, 178
 Mechanical dividers, 89
 Meridians
 defined, 163, 206
 geographic, 206
 prime, 163
 principal, 274
 true, 206
 Metes and bounds, 270–271
 Metric scales, 93–96
 Metric-to-U.S. conversions, 93, 95
 Middle ordinate (M), 315
 Mil, 14
 Military maps, 14
 Mill. *See* Milliradian
 Milliradian, 14, 204
 Minor contours, 236
 Mobile GIS, 452
 Mobile ground-based laser scanning,
 152–154
 Mobile laser scanning (MLS). *See* Mobile
 ground-based laser scanning
 Mobile mapping. *See* Mobile ground-
 based laser scanning
 Mobile terrestrial laser scanning. *See* Mo-
 bile ground-based laser scanning
 Model files, 73

Modeling, GIS, 469–470, 472
 Model space system, 70, 71, 96
 Monument (MON), 181, 270, 271

N

National BIM Standard-United States
 (NBIMS-US), 53
 National Geodetic Survey (NGS), 132
 National Institute of Building Sciences
 (NIBS), 34
 National Spatial Reference System
 (NSRS), 132, 179
 National standards, 54
 Natural resource management, 464
 Nautical charts, 19
 Navigation Signal Timing and Ranging
 GPS (NAVSTAR), 146
 Nearest-neighbor, 462
 Negative departures, 218
 Negative latitude, 218
 Network analysis, 462
 NIBS (National Institute of Building Sci-
 ences), 34
 NIBS buildingSMART alliance, 53
 North American Datum 1927
 (NAD 27), 172
 North American Datum 1983 (NAD 83),
 162, 172
 North American Vertical Datum of 1988
 (NAVD 88), 237
 North latitude, 163
 Notes. *See also* Field notes
 general discipline notes, 62
 general sheet notes, 62
 local, 61
 specific, 61, 62
 and specifications, 60–62
 Numerators, 86
 Numerical scales, 86–87

O

Oblate spheroids, 130, 160
 Obtuse angle, 206
 Occupational overuse syndrome
 (OOS), 76
 Odometer, 178
 Offset distance formula, 379
 1:250,000 scale maps, 87
 Open source application, 452
 Open traverses, 212
 Optical-micrometer level, 185
 Origin point, 160
 Orthophotos. *See* Aerial photographs

P

Pacing, 177
 Paper space system, 70, 71, 96
 Parallels, 162
 Parallels of latitude, 162
 Parameter, 118
 Parametric Technology Corporation (PTC),
 47–48
 Pedometer, 178
 Percent grade, 378
 Perpendicular, 206
 Photogrammetric maps, 11
 Photogrammetric surveys, 134, 137, 138
 Photogrammetry, 11, 134, 471. *See also*
 Aerial photographs
 Physical maps, 10
 Pictorial view, 411
 Pipe laser level, 186
 Piping, 419, 431–433

Pitney Bowes, Inc., 453
 Pixels, 459
 Plan
 defined, 27, 262
 view, 27, 262
 Plane
 defined, 132
 surveys, 132–133
 Planned unit developments (PUDs), 270
 Planning maps, 18–19
 infrastructure, 18
 Planter area, 409, 411
 Plats, 262. *See also* Plots, plans
 Plots
 defined, 17, 215, 262
 device, 70
 plans, 17, 262
 Plotting traverses, 215–221
 PLSS. *See* Public Land Survey System (PLSS)
 Plumb bob, 179
 Plumb laser level, 186
 Plunged, 213
 Plus station, 310
 Point cloud, 151
 Point feature, in GIS, 457
 Point-in-polygon, 462
 Point of beginning (POB), 212, 213
 Point of curvature, 314
 Point of curve (PC), 314
 Point of intersection (PI), 314
 Point of reverse curve (PRC), 315
 Point of tangency (PT), 314
 Political maps, 10
 Polygon
 defined, 206
 feature, 457
 overlay, 462
 Positive departure, 218
 Positive latitude, 217
 Potable water, 279, 416
 Poured-in-place concrete construction, 420, 434
 Precast concrete construction, 420
 Precision leveling, 185
 Prime meridian, 163
 Principal meridians, 274
 Principles and Practice of Engineering (PE), 5
 Professional engineer (PE), 4
 Professional organization standards, 34–35
 Profiles, 28, 381
 Project files, 73
 Project management, 471
 Project map, 262
 Project standards, 35–36
 Prolongation, 212
 Property surveys, 134
 Public Land Survey System (PLSS), 13, 210, 270–273
 Public utility easement (PUE), 279
 Pythagorean theorem, 165, 167–168

Q

Quadrangle maps, 12–13, 175, 229
 locations on, 175
 Quantities, 249
 Quantity take off (QTO), 53
 Query, 458

R

Radial surveys, 247
 Radian, 168, 204

Radiation, 247
 Radius (R), 314
 Ranges, 276
 Raster data format, 459–460
 Rasterization, 460
 Rear tangent, 314
 Rectangular coordinate system, 160
 Rectangular system
 basic reference lines, 274
 PLSS, 272–273
 sections, 276–277
 subdivision of sections, 277
 townships, 274–276
 Reference lines, basic, 274
 Reference points, 132
 Reflex angle, 205
 Region feature, in GIS, 457
 Regular polygon, 206
 Reinforced concrete, 421, 435
 Relational database management systems (RDBMSs), 458
 Relief symbols, 108, 111, 112
 Remote sensing, 20, 155, 156, 471
 Repetitive movement injury (RMI), 76
 Repetitive strain injury (RSI), 76
 Repose, angle of, 372–374
 Representative fraction (RF), 86–87
 converting from graphic scale, 90–92
 defined, 86
 Reverse curve
 defined, 313
 point of, 315
 Ridge, 231–232
 Right angle, 205, 206
 Right-hand curve, 314
 Roads. *See also* Horizontal alignment
 layout
 detail drawings, 409–413
 inclined, 377–379
 Roadway cut and fill layout, 372–378
 basic layout procedure, 376–377
 inclined road layout, 377–379
 Robotic total stations, 139, 140
 Rotating beam laser level, 185
 Route feature, in GIS, 457
 Route surveys, 137, 139
 Rover, 149
 Rural residential fire department access, 286–287

S

Saddle, 232
 Sanitary sewers, 280–281, 416, 422, 423
 Satellites
 constellation, 146
 GPS, 146–147
 Scale factors, 72, 97–99
 Scales
 bar, 87
 CADD, 96–99
 defined, 10
 drawing, 70
 engineer's, 92, 93
 graphic, 87–92
 metric, 93–96
 numerical, 86–87
 verbal, 92
 Scaling and scale factors, 72
 Schedules
 defined, 63, 64
 module, 63
 Sections
 defined, 276
 subdivision of, 277

Selective availability (SA), 149
 Self-reading rods, 184
 Septic tank, 282
 Server GIS, 452
 Setbacks, 282
 Sewage disposal methods, 279–282
 Sewers
 combined sewerage outlet, 411
 sanitary, 280–281, 416, 422, 423
 storm, 281–282, 411, 415–418
 Sexagesimal system, 162, 204
 Shaded relief maps, 87
 Sheet files, 73
 Sheet format, 67–69
 Sheet identification standards, 67, 68
 Sheet sizes, 66–67
 Shot, 142
 Side shots, 247
 Sidewalks, 409, 411
 Siemens Corporation, 48
 Simple curve
 components of, 313–315
 curve layout, 315–317
 defined, 312
 Site plans. *See also* Plots, plans
 adding structures and utilities, 288–290
 completing, 291–292
 cut and fill layout, 378–380
 defined, 17, 262, 267
 layout, 287–292
 requirements, 262–270
 rural residential fire department access
 and site planning, 286–287
 sewage disposal methods, 279–282
 site design considerations, 282–287
 utilities, 279
 SketchUp software, 48
 Slopes, uniform slope theory, 238
 Sludge, 282
 Slurry pipelines, 279
 Small-scale maps, 87
 Soft copies, 70
 Software
 AutoCAD Civil 3D, 47
 CADD, 4
 GIS, 452–453
 SketchUp, 48
 Soil absorption field, 282
 South latitude, 163
 Space segment, 147
 Spatial
 analysis, 461–462
 data, 456–458
 defined, 452
 queries, 462
 SPCS. *See* State Plane Coordinate System (SPCS)
 Special maps, 87
 Specifications, Project, 36, 62
 Specific notes, 61, 62
 Speed humps, 409, 412
 Spherical excess, 168
 Spherical triangle, 168
 Spherical trigonometry, 168
 Spheroids, oblate, 130
 Spiral curve, 313
 Spirit leveling, 181
 Spot elevations, 144
 Spreadsheets, 454
 Stadia, 179
 Standards
 CADD, 54
 checking, 36
 defined, 32
 details, 408–440

State Plane Coordinate (SPC), 206
 State Plane Coordinate System (SPCS), 172–174
 Static terrestrial laser scanning. *See* Stationary ground-based laser scanning
 Stationary ground-based laser scanning, 151–152
 Stationing locates station (STA), 310
 Station points, 211
 Statistics, 471
 Statute mile, 163
 Steel detail drawings, 422, 438
 Storm sewage, 280, 411
 Storm sewers, 281–282, 411, 415–418
 Straight angle, 205
 Streets. *See* Roads
 Structural detail drawings, 419–422, 434–438
 Subdivision
 defined, 17, 262
 plans, 270
 of sections, 277
 Supplementary contour, 237
 Surveying
 conventional ground surveying, 139
 data collection, 139–141
 defined, 2, 130
 field notes, 142–145
 and GIS, 471
 Surveyors, 23, 130
 level, 181
 local control points, 182
 Surveys, 130–139
 as-built, 137–138
 construction, 137, 140
 control, 133–134
 control point, 238
 cross sections, 381, 383–384
 data output and point coding, 142–145
 geodetic, 130–132
 grid, 242–243
 hydrographic, 134, 136
 land, 134, 135
 photogrammetric, 134, 137, 138
 plane, 132–133
 radial, 247
 route, 137, 139
 topographic, 134, 136
 Symbols
 CADD, 64–65, 115, 116
 culture, 108–111
 graphic patterns, 115
 libraries, 64, 118–121
 relief, 108, 111, 112
 tools, 115–118
 topographic map, 108–111
 vegetation, 113, 114
 water, 111, 113

T

Tables, 63–64
 Tangency, point of, 314
 Tangent distance (T), 314
 Taping, 178
 TBMs. *See* Temporary bench marks (TBMs)
 Template drawings, 76
 Temporary bench marks (TBMs), 182
 Terrain, 14

Text, 58–60
 fonts, 58
 heights, 59–60
 styles, 58–59
 Thematic maps, 10–11
 3D analysis, 470, 472
 Three-dimensional (3-D)
 analysis, 469–470
 defined, 2
 design, 46
 laser scanner, 151
 model, 96
 Thrust blocks, 417
 Tick mark, 175
 TIGER (Topologically Integrated Geographic Encoding and Referencing), 467
 Tilt-up concrete, 420–421
 Title block, 8
 Topographic maps
 defined, 12, 229
 symbols, 108–111
 Topographic surveys, 134, 136
 Topography, 228
 Topologically Integrated Geographic Encoding and Referencing (TIGER), 467
 Topology, 460
 Total stations
 defined, 139, 140
 robotic, 139, 140
 Townships, 274–276
 Transition curve, 313
 Transit lines, 247
 Transit station, 247
 Traverse
 defined, 211
 plotting, 215–221
 stations, 211
 Traversing, 211–215
 angles-to-the-right, 213–214
 azimuth, 214–215
 closed traverse, 212, 215–217
 connecting traverse, 212
 deflection angles, 212–213
 interior angles, 212
 loop traverse, 212
 open traverse, 212
 Triangular engineer's scales, 92, 93
 Triangulated irregular network (TIN), 143, 144, 248, 310
 Triangulation
 defined, 130–132
 stations, 131
 Trigonometry, spherical, 168
 Trilateration, 148
 True azimuth (TA), 209
 True bearings, 211
 True meridian, 206
 True north (TN), 175, 206
 Turning point (TP), 182–183, 383
 Two-dimensional (2-D)
 defined, 2
 design, 46
 model, 96
 Typical cross section, 30, 381, 382
 Typical detail, 407, 409

U

UniFormat library file naming system, 73
 Uniform slope theory, 238

Universal Transverse Mercator (UTM), 169, 206
 Unmanned aerial system (UAS), 155, 156
 Unmanned aerial vehicles (UAVs), 155, 156
 Uppercase text, 59
 U.S. Air Force, 146
 U.S. Bureau of Land Management (BLM), 272
 U.S. Census Bureau, 467
 U.S. Coast and Geodetic Survey (USC&GS), 172
 User segment, 148
 U.S. Geological Survey (USGS), 175, 229, 455
 U.S. National CAD Standard, 34, 54
 building information modeling (BIM), 49–53
 U.S. National Geodetic Survey (NGS), 163
 U.S. survey foot, 172
 U.S.-to-metric conversions, 93, 95
 Utilities management, 469
 Utility easement, 279
 UTM (Universal Transverse Mercator), 169

V

Vector data format, 459
 Vectorization, 460
 Vegetation symbols, 113, 114
 Verbal scale, 92
 Vertex, 204
 Vertical alignment, 310
 Vertical datum, 179, 237
 Vertical distances, 179–187
 construction laser levels, 185–187
 leveling, 181
 leveling example, 183–184
 leveling field data, 185
 leveling process, 181–183
 level rod reading, 184
 precision leveling, 185
 Vertical text, 59
 Vicinity maps, 27, 262
 Viewshed determination, 470
 Virtual, CADD, 48
 Voxel feature, in GIS, 457

W

Water detail drawings, 416–418, 427–430
 Water features, 111, 113
 Water meters, 418, 430
 Water symbols, 111, 113
 wblock, 119
 Web GIS, 452
 West longitude, 164
 West magnetic declination (WMD), 208
 Wildfire zones, 287
 Wood detail drawings, 422, 437
 Wood-frame construction, 422, 437
 Workplace ethics, 36
 Workstations, 77–78
 World Geodetic System of 1984 (WGS 84), 161

Z

Zoning
 defined, 267
 maps, 19
 Zoom, CADD, 96